7 COASTAL MANAGEMENT ISSUES

Convenors: Dr. Carl Hershner and Ms. Geraldine McCormick-Ray

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A WATERSHED PERSPECTIVE FOR CHESAPEAKE BAY MANAGEMENT

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Abstract: Sustainability is a goal that is widely talked about. Ludwig and associates (1993) challenge the concept by looking at the history of resource exploitation, which shows that natural resources are inevitably over exploited, often to the point of collapse or extinction. This overexploitation is attributable in part to the focus of resource management, whose efforts are directed at the "products" of ecosystems without an equal effort to protecting the higher levels of watershed control. This paper suggests that management efforts directed at protecting, sustaining, or restoring estuarine resources should include the maintenance of the watershed processes that sustain estuarine habitats over time. Chesapeake Bay provides an excellent example in which to examine estuarine resource sustainability in the context of watershed structure and change.

The target species of the Chesapeake Bay Program, the ecologically valued habitats such as wetlands, seagrass beds, and oyster reefs, and protected areas are valued ecosystem products of the Chesapeake Bay. They are sustained by hierarchical processes occurring over the watershed, a defensible ecosystem unit with diverse habitats that contribute resiliency and continuity in the face of estuarine change. Freshwater creates salinity zones and it connects the watershed habitats, representing an important environmental process to the protection, sustainability, and management of valued species and habitats. Fresh water also provides a mechanism for ecosystem accounting, a kind of common currency on which to measure human impact. It connects the people to the Bay's resources and the resources to the people.

A watershed and fresh water focus provides managers with a perspective on resource sustainability that is otherwise lost in a complicated system of lower-level governance. Alignment of governance with resource needs at a watershed level requires public understanding to gain the necessary political support for whole watershed management. Public understanding may be facilitated when common currencies such as fresh water are shown to connect the people to the sustainment of valued resources and habitats. Oyster reefs and protected areas need to be promoted, as they help flag public attention and can serve to indicate loss of estuarine function.

INTRODUCTION AND DISCUSSION

A watershed approach is fundamental to the management of estuarine resources. Estuarine ecosystems are a part of a hierarchy of interactions, with interdependencies and feedbacks that relate the resources upward and downward as well as horizontally across the system. Hierarchical mechanisms contribute stability and resiliency through repair and redundancy, and these mechanisms are sustained by environmental inputs observed at the watershed level. Identification of environmental controls within this context helps relate human uses and resource management to the evolution and ecology of the entire watershed ecosystem. Control mechanisms such as freshwater input contribute to the structure and function of the watershed ecosystem and link valued resources to whole watershed changes.

Resource management focuses on the "products" of ecosystems without an equal effort being given to understanding and protecting the higher levels of control. It concentrates on maximum output of economically valued species, guided by perceptions of resources as commodities rather than by a perception of ecosystem inputs that sustain production. It works to restore habitats by technological subsides rather than by ensuring watershed function. Furthermore, management directives mostly are a patch-work of jurisdictions narrowly focused on social and political values that emphasize human uses and encourage developments that interfere with watershed functions on which natural resources depend.

Resource problems result when natural resources are disconnected from their ecological supports, then to be squeezed further by disturbances and discontinuities in the natural system as they seek to recover. Disturbances, periodic and aperiodic, are characteristic features of estuarine systems. They force change, requiring higher-level ecosystem repair mechanisms to ensure estuarine resiliency and maintain estuarine function. Environmental change can separate a species from its support mechanisms at any scale of the hierarchy, as estuarine species are restricted by physiology, life history, and habitat needs.

Resource management needs to focus on higher levels of organization to avoid the mismatch between the way in which the watershed functions and the way in which resources are managed. Chesapeake Bay provides an excellent example in which to examine estuarine resource sustainability in the context of watershed structure and change. This paper suggests that management efforts directed at protecting, sustaining, or restoring the products of estuarine ecosystems are inappropriately focused and that efforts should be directed toward maintaining the watershed processes that sustain the habitats over time.

Valued Products

Valued ecosystem products of Chesapeake Bay include the target species of the Chesapeake Bay Program, as well as the ecologically valued habitats such as wetlands, seagrass beds, and oyster reefs that contribute to estuarine function and to its productivity. Included as well are protected areas and management areas that contain species and habitats also valued by society. Target species and valued areas are protected by legal authority and sustained by ecosystem processes, or by expensive technological intervention, or a combination of both. All of these valued products depend on watershed processes.

The Chesapeake Bay Living Resources Program has identified 31 target species selected from a larger list of representative species (Funderburk et al. 1991). Those listed span the Chesapeake Bay system in widespread distributional, life history patterns that cross the entire watershed system. The target species occur in all salinity zones and major habitats (land and water) (tables 1a, 1b). They cross trophic levels and phyletic groups and provide a perspective for watershed management.

The target species show spatial organization. They have adjusted to environmental changes and to ecological disturbances that have occurred during the past 15,000 years of sea level rise and climate warming. They have evolved through survival mechanisms in response to seasonal change, tidal amplitudes, and storm events. Salinity, season, and habitat restrict their distribution, behavior (feeding, life history; tables 1a, 1b), and population levels. The distributional patterns of their various life history stages (Funderburk et al. 1991) are organized into biogeographical pattern that span the Bay's entire watershed. This spatial organization is determined in part by the physiological tolerances of the species to physical factors and to suitable habitat. All life history stages and distributions define patterns of biotic assemblages across the watershed.

Temporal patterns are observed as well. Species enter and concentrate in the Bay in summer months where they feed, breed, and eat; a period when the frequency of storms is much reduced (Dolan et al. 1988), salinity fluctuation is least extreme, and water stratification occurs. In summer months, abundant plankton is produced, which is available to the numerous filter feeders in the Bay. Filter feeders connect lower trophic levels to higher levels of biotic organization. The total production in the summer months is stored for winter visitors, such as the two target species, canvasback and redhead ducks, which thrive in the Bay during the period of low winter productivity. The target species represent different trophic levels, for example, primary production (submerged aquatic vegetation, or SAV) and primary consumers (invertebrates), and these sustain the fishes and birds in complex associations across the watershed. Hence, the target species show relational connections to the spatial and temporal organization of the watershed system.

Watershed Structure and Connectivity: The Role of Fresh water

The watershed is a defensible ecosystem unit (Ray and Hayden 1992) on which to focus manage-

Table 1a. Adult target species. Sources: Abraham and Dillon 1986, Funderburk et. al. 1991, Richkus et al. 1994, Sellers and Stanley 1984.

Type	Salinity (ppt)	Major Food Type	Habitat	Time Period (critical)	Population Behavior
Submerged Aquatic Vegetation					
Wild celery *Vallisneria americana*	0-5	autotrophic	littoral	April-Sept	Resident
Sago pondweed *Potamogeton pectinatus*	0-12	autotrophic	littoral	April-Sept	Resident
Redhead grass *Potamogeton perfoliatus*	2-19	autotrophic	littoral	April-Sept	Resident
Widgeon grass *Ruppia maritima*	5-60	autotrophic	littoral	April-Sept	Resident
Eelgrass *Zostera marina*	5-35	autotrophic	littoral	April-Sept	Resident
Invertebrates					
Soft shell clam *Mya arenaria*	10-25	phytoplankton	littoral-benthic	Oct-Dec May-June	Resident
Hard clam *Mercenaria mercenaria*	12-35 prefers >20	phytoplankton	benthic	May-Oct	Resident
Eastern oyster *Crassostrea virginica*	5 - 35	phytoplankton	benthic	June-Oct	Resident
Blue crab *Callinectes sapidus*	2-21	plankton; detritus	benthic	June-Oct	Resident
Fish					
Atlantic menhaden *Brevoortia tyrannus*	0-35	plankton	pelagic	April-Oct	semimigratory
Bay anchovy *Anchoa mitchilli*	0- 80	plankton	pelagic	May-Sept	Resident
American shad *Alosa sapidissima*	0-35	plankton	pelagic	Feb-June	migratory anadromous
Hickory shad *Alosa mediocris*	0-35	plankton	pelagic	March-May	migratory anadromous
Blueback herring *Alosa aestivalis*	0-35	plankton	pelagic	April-May	migratory anadromous
Alewife *Alosa pseudoharengus*	0-35	plankton	pelagic	March-May	Resident anadromous
Spot *Leiostomus xanthurus*	0-32	fish, invertebrates	demersal	April-Nov	semimigratory
White perch *Morone americana*	0-18 prefer 13-18	fish, invertebrates	pelagic	March-June	semi-anadromous
Striped bass *Morone saxatilis*	0-25	fish, invertebrates	pelagic	April-June	migratory anadromous
Yellow perch *Perca flavescens*	0.5-13	fish,	pelagic	Feb-May	semi-anadromous
Birds					
Wood duck *Aix sponsa*	Fresh, brack	seeds vegation	marsh wetland	April-Oct	migratory
American black duck *Anas rubripes*		SAV invertebrates	marsh wetland	March-June	migratory
Canavasback *Aythya valisneria*	Fresh brack	SAV, fish, invertebrates	marsh wetland	Nov-March	migratory
Redhead *Aythya americana*	Fresh brack.	SAV invertebrates	marsh wetland	Nov-March	migratory

Table 1a. (continued)

Type	Salinity (ppt)	Major Food Type	Habitat	Time Period (critical)	Population Behavior
Birds					
Great blue heron *Ardea herodias*	varied	fish, varied	marsh wetland	Feb-Dec	Resident resident
Little blue heron *Egretta caerulea*	fresh	aquatic varied	marsh wetland	April-Oct	migratory
Black-crowned night heron *Nycticorax nycticorax*	varied	omnivorous	varied	Feb-Oct	resident
Green-backed heron *Butorides striatus*	varied	fish, aquatic invertebrates	marsh wetland	April-Oct	migratory
Great egret *Casmerodius* spp.	varied	fish invertebrates	marsh wetland	March-Sept	migratory
Snowy egret *Egretta thula*	varied	fish	marsh wetland	April-Sept	migratory
Osprey *Pandion haliaetus*	varied	fish	marsh estuarine	March-Sept	migratory
Bald eagle *Haliaeetus leucocephalus*	N / A	fish, carnivore	wetland forested	March-Sept	resident\ seasonal

Table 1b. Life history stages and salinity zones.

Target Species	Salinity
Invertebrates	
Soft shell clam: larvae	> 10.5
Hard clam: eggs & larvae	> 17.5
optimum	26.0 - 27
Eastern oyster:	
eggs	16.0 - 30
larvae	3.0 - 31
Blue crab:	
Females prefer:	10.0 - 35
Males prefer:	3.0 - 15
Fish	
Atlantic menhaden: juvenile	0.0 - 34
Bay anchovy	
larvae:	4.2 - 6
eggs:	0.0 - 7
American shad:	
eggs	0.0 - 5
larvae	7.5 -15
Hickory shad:	
eggs	0.0 - 5
larvae	7.5 - 15
Blueback herring: eggs & larvae	0.0 - 5
Alewife: eggs & larvae	0.0 - 5
Spot: Juveniles	0.0 - 32
preference	13.0 - 25
White perch:	
eggs & larvae	0.0 - 8
juveniles	0.0 - 8
Striped bass: larvae & juvenile	0.0 - 5
Yellow perch: eggs & larvae	0.5 - 19

ment. The Chesapeake Bay watershed ecosystem has physical boundaries (U.S. Environmental Protection Agency, 1983) that delimit an area of 64,000 sq. mi. The watershed ecosystem may be viewed as a nested system of physiographic land/seascapes, a variety of habitats, and a multitude of human institutions with fragmented management jurisdictions. Ocean and climatic forces produce flux and change in a dynamic interplay of hydrology, biology, geology, and chemistry. The flux of fresh water into and out of the Bay carries watershed products that exert an influence over the continental shelf for many kilometers, defining the seaward boundary of the watershed system.

The diverse habitats of the watershed create a mosaic of ecologically interdependent land/seascape patterns that contribute resiliency and continuity to the estuarine system. They support dynamic associations of species. They filter, trap, and release sediment, nutrients, and materials across the watershed system. They are exposed to daily, seasonal, and episodic changes, yet they continue to function with high productivity and rapid restoration of function. In this complex web of associations, estuarine species seek diverse habitats cross the watershed system, and the variety of habitats contribute to the Bay's characteristic productivity, species diversity, and system resiliency.

Fresh water is of paramount importance for the structuring of the watershed system. Freshwater input, together with tidal exchanges, plays an essential role in the maintenance of habitats on which target species depend. These habitats include fresh-and saltwater marshes, structural features of the water column, intertidal mud flats, and benthic communities including seagrass beds, clam beds, and oyster reefs. Interactions of fresh water and seawater in summer months create isohaline boundaries that structure the pelagic environment and form, in combination with other environmental factors, water column stratification, and estuarine fronts that support pelagic assemblages of species. Stratification affects the exchange of gases important to the creation of anoxic zones, the transport of particles, and the fate of nutrients released from the benthos. As salinity is a critical factor in establishment of estuarine fronts (Seliger et al. 1981), it is important to the movements and distribution of planktonic organisms and their diversity and abundance. For example, the dinoflagellate *Katodinium rotundatum* bloomed in the stratified water of the Potomac and remained in the same area for 4-5 months under a period of high freshwater flow. When there was a period of low flow, a mixed population of planktonic species occurred (Smetacek l986). Oyster larvae, as well, depend on fronts and water stratification to colonize in their parental locations and to build complex reefs. Furthermore, species assemblages are associated with salinity (Bulger et al. 1993, Ladd et al. 1957) and define a Chesapeake Bay watershed biogeographical organization (U.S. Environmental Protection Agency, 1983, Funderburk et al. 1991).

These salinity-defined biogeographical patterns describe assemblages of species whose combined productivity sustains both resident and transient or semimigratory species' populations, including target species (table 1a). Many of the target species are restricted to narrow salinity ranges that change with life stages (table 1b) and life history events. Estuarine species seek optimum-habitat conditions to carry out life history needs, such as reproduction and larval settling. Some species remain in local areas while others are far-ranging. Anadromous and catadromous species visit the Bay and span the watershed, contributing significant amounts of marine-derived animal detritus to tidal and non-tidal freshwater systems (Garman 1992).

Fresh water is an environmental connector in the watershed system. It penetrates over and through the landscape. Through the landscape, submarine groundwater, which couples the land and water environments as do surface discharges, delivers to Chesapeake Bay a volume of fresh water of the same magnitude as major tributaries (Simmons and Reay l99l, Simmons et al. 1991). Fresh water connects the habitats and species to the dynamics of the watershed system, as channels act like conduits to carry water and species and transport nutrients and other materials. Freshwater flows deliver energy, particles, and chemicals that mix with saline water driven landward by tidal forces. Freshwater flows are affected by seasonal, annual, and interannual variations in precipitation and runoff. Extreme low and high flows create a salin-ity range for tolerant species. In the Chesapeake Bay, average flow rates vary within the year, with higher-than-average flows occurring in late winter and spring and lower rates in midsummer and fall. The watershed can experience extraordinary conditions about every 20 years (U.S. Water Resources Council 1978). Freshwater flows interact with tidal dynamics in shallow regions near shores and in the middle reaches of estuaries, where the interactions are most intense. The interaction of fresh water and tides affects benthic topography, water column structure, species distribution, shoreline change, and coastal aquifers. When freshwater flows are reduced, sea-water intrudes into the coastal aquifers to fill the space, weaken shore integrity, and exacerbate erosion. Also, fresh water and tides contribute sed-iment that is deposited and fills basins, building new land areas in a dynamic interplay of land, sea, and climate.

Environmental fluxes and habitat availability result in dynamic equilibrium of species associations. Some populations flourish and others become rare, endangered, or extinct in a competitive web of interactions across the watershed. The flush (rate, duration, and timing) of predictable and stochastic freshwater flow influences the quality and quantity of suitable habitats. Flow rates affect species associations and sustain assemblages that are dependent on externally generated nutrients. Currents deliver species to preferred habitats at the needed time, but may deliver them to habitats subject to seasonal or storm events. The habitat may then be marginal to their needs. As some species may become displaced, they may be rescued by another habitat, as habitat redundancy provides system resiliency with the process of change. Estuarine connectivity ensures maintenance and restoration of ecosystem function while habitat redundancy provides alternative choices for displaced species. Excesses numbers of individuals can colonize newly created habitat and give the system a robust character.

The Need for Top-Down Management

Management should focus on interchanges across the watershed system. It should incorporate the monitoring and management of keystone species and their interactions with habitats. It should maintain the continuity of habitats, with each other and with the physical environment. It should ensure that the integrity of the system is intact and that it can rebuild habitat in response to change. These management directives require a fundamental shift in management. Management of individual species for its production will fail unless the processes that sustain the species in its communities is made a part. Unless a watershed focus is prescribed, management of protected areas or valued habitats, as with species management, will be vulnerable to change.

The Eastern Oyster

Oysters are a target species and an important "keystone" species in the Bay system, and management is attempting to restore reef habitat. Oysters are not only an important food source for estuarine animals and a commercial product for humans, but they also provide a critical habitat for a diverse community of benthic organisms. They are a "quintessential" estuarine species (Bahr and Lanier 1981), having evolved over millennia to thrive in mesohaline waters in the benthic seascape. They generally tolerate short exposures to anoxia, freshwater, sediment, air, and changes in ambient temperatures, which are characteristic features of the Bay. In summer months, they are reproductively active. They contribute spawn as food particles for filter feeding organisms when climate, freshwater flow, and water column structure are optimal. Oysters grow best where there is firm substrate and suitable material for larvae attachment in the central salinity regions of estuaries, where they are exposed to infrequent flooding and a range of tidal fluxes. Over generations of time, they build hard, complex reefs (Funderburk et al.1991, Stenzel 1971) to provide a structural benthic feature in an otherwise mobile sand and mud environment.

Oyster reefs occur at the edge of land and sea, in the middle portions of estuaries. They connect with the watershed system through such processes as freshwater, sediment, nutrient, and species flows. Oyster reefs form best in tidal channel meanders, where their distribution reflects geologic, hydrologic, and biologic interactions (Bahr and Lanier 1981, Keck et al. 1973) over decades to centuries of time. Their occurrence in the benthic seascape affects water flow patterns, particle movements, and benthic conditions that reflect up through the system. They interchange nutrients with other estuarine habitats via tidal creeks (Childers et al., 1993). They move organic matter vertically through the water column as their gametes nourish filter-feeding consumers during the summer's abundance, and, through deposition of feces, shell, and particles, they provide nutrients for valued benthic species, including fishes that utilize the reefs in summer (Newell 1988, Newell and Breitburg 1992), and fishes may become extremely abundant around reefs. Reefs exhibit temporal change, acting as feeding stations to attract larger predators that may feed in and around the reef by day, night, season, or in biannual or interannual visits through the estuary. As rigid habitats in an otherwise soft bottom environment, reefs contribute complex living space to sustain a diversity of sessile and cryptic species that also show temporal changes. Reefs support valued target species that seek shelter, food, or rest during particular life history stages or during migrations through the watershed. Oyster reefs are also important as hard dead substrate, structuring the benthic community, stabilizing the substrate, restricting infaunal habitat space, and contributing to epizotic species richness in taphonomic feed-back (Kidwell and Jablonski 1983). Hence, as islands of hard living and dead substrate that occur along a wide salinity range, they provide habitat for a seasonally changing composition of species, and connect vertically and horizontally with other habitats, as well as provide habitat alternatives for species displaced by environmental change. At the spatial scale of their distribution in the middle of estuaries, they connect with the watershed system.

Oyster reefs contribute to the natural productivity, character, and resiliency of the estuarine system. They flourish in mesohaline waters, where they provide a stabilizing influence as a hard substrate in an otherwise mobile system. They play an important role in filtering Bay water (Newell 1988). Their distribution reflects current flow patterns as they act to buffer the shore against the effects of moderate storms and tidal action. Through sediment entrapment and feces deposition, they can elevate the level of the benthos. In a dynamic interplay of water flow, disturbance, and redevelopment of landscapes, they contribute to marshland construction and its erosion (Bahr and Lanier, 1981). And as habitat, they provide hard substrate for other species to attach and find food and shelter.

The reef structure is constrained by conditions established by the watershed system. As a set of complex communities responding to conditions of natural change along a continuum of change, their occurrence, distribution, and associated species are affected by and they affect the watershed system itself (Bahr and Lanier 1981, Dame et al. 1992). Reefs are affected by benthic topography, anoxic waters, sedimentation, tidal exchanges, current flows, and freshwater quality, quantity, and duration of exposure. Reefs thrive in the middle regions of estuaries, restricted by salinity and predators. In Chesapeake Bay, they occur subtidally, affected by freezing and aerial exposures. They are also vulnerable to swift currents, soft benthos, and to nutrient and pollutant loading delivered from the watershed. Over long periods of time, reef communities degenerate and rebuild in a continuum of destruction and repair, when storms and natural change alter the physical conditions.

While management has focused on oyster production, the ecological functions of reefs have mainly been lost. Today, oyster reefs are mere remnants of their former extent (Ingersoll 1881, Kennedy and Breisch 1983, Winslow 1882). While the oysters are affected by the loss of suitable habitat (Seliger and Boggs 1988) in which to settle and build reefs, reefs are affected by overharvesting, by habitat alteration, and by general mismanagement of the fisheries and estuary itself. The oysters that do survive are further threatened by disease, and these are experiencing recovery difficulties. The surviving reefs are further challenged by changes in the watershed system, such as, rates, quality, and timing of freshwater flows that deliver loads of sediment, affect current flow rates, change salinity patterns, and creates anoxic zones. The focus of management should be on protecting the processes that sustain oysters and their reef building capacity. While some species play minor roles in the watershed system, the Eastern oyster plays a fundamentally important role. And while sustainment of the reef is critical to a dependent community, the sustainment of the reef system may be critical to the estuarine system in which it has evolved. Its lost position in the estuary may adversely influence estuarine processes and repair mechanisms, and reduce the system’s capacity to support valued species. The sustainability of oyster reefs is tied as much to the estuarine system and to freshwater flows as it is to human harvests, pollution, and dredging. Hence, the appropriate management response is at the watershed level, with monitoring of the important linkages (e.g., freshwater) that connect the valued species to landscape patterns and to habitat repair. The impact of the oyster’s lost function, biologically and ecologically, may reflect up through the system to affect the conditions on which other species and habitats depend, on time scales beyond a single manager’s focus, and in yet-unknown ways .

The variety of estuarine habitats available to the variety of species further adds to the character of the Bay and to its productivity. Habitats such as freshwater and saltwater mashes, aquatic grasses, the water column, clam beds, mud flats, and oyster reefs exchange and support species that society values. Individually, habitats provide the structural base of the estuarine system. They are molded by environmental forces and inhabited by species that adapt and flourish. Collectively they form a matrix of interactions that sustain the Bay’s character.

Protected Areas

Many of the habitats are protected by legal mandates or managed for their restoration. Within the Chesapeake Bay watershed system there are many local, state, federal, and private protected areas. These fall under many separate authorities and mandates. They include national wildlife refuges, state management areas, private ownerships, artificial oyster reefs, and others. Protected areas represent patches, or mosaics, of valued assets.

In many cases, protected areas contain the remaining vestiges of the natural, original system. They capture a piece of history in Chesapeake Bay's rich environmental past, preserved within defined borders, and managed to sustain many of the Bay's natural attributes. In the watershed, protected areas cover approximately 1 billion hectares as national wildlife refuges, federal national parklands, federal national forestlands, military bases, state parklands and forestlands, and local ownerships (Hahn 1989). They form geographic patches that support the target species. Protected areas have wide public appeal, being valued not only for habitat and species protection and recovery, but also because they attract tourist dollars to local communities. Some include large tracts of natural marshland and an abundance and diversity of species. In many cases, they have been created to preserve some traditional uses, like fishing and huntingwhich were highly valued when these resources were plentiful. State-protected areas include wetlands, whose ecological benefits are defended against traditional human encroachments.

Changes in the watershed system affect the species and habitats that protected areas aim to protect. They, as with species, habitats and coastal counties, can be squeezed by change (table 2) and threatened by human impacts that occur outside their borders. The habitats they protect may be unable to accommodate accelerated watershed change, human uses, and shoreline erosion. The natural forces of change will affect those attributes that protected areas aim to sustain, requiring that they be given larger management budgets to subsidize habitats, meet species needs, and fulfill legal mandates. Erosional shorelands and costs of shoreline stabilization will assume greater shares in an era of tighter budgets. Hence, as islands fragmented from the natural system and disconnected from their ecological links, protected areas become expensive to manage and vulnerable to change.

Protected areas can act as sentinels of watershed change. The observed changes in resource abundance or in ecological processes that occur at the level of the individual protected area can be related upward to higher levels, to signal changes occurring in the watershed. The individual site could call attention to threats and concerns at the local level, or those occurring in particular subregions. Their management needs might be grouped with other areas exhibiting the same concerns. Collectively as a network, protected areas can contribute information about the status and trends of the estuarine system and its important habitats, as they relate natural resource problems to the larger watershed or regional scale. To monitor watershed change, data on protected areas can be related to resource changes and scaled to the level of Chesapeake Bay.

Resource Management: A Moving Target

Natural resources exhibit high and low peaks in harvest abundance recorded over long time spans. For each species, general trends are observed when the peaks and valleys are smoothed out. A declining harvest trend is observed in the anadromous fishes (shad and river herring), the hard clam, the oysters, and the canvasbacks ducks, while spot, blue crabs, and soft shell clam harvest abundance appears highly variable (Richkus et al. 1994). Seagrasses have virtually disappeared but show signs of some recovery. Habitat changes, overharvesting, and pollution are held responsible for the declines while human changes over the entire watershed are generally inferred. Yet habitat disconnectivity over the watershed is forcing change and squeezing the resources between human developments and natural change.

The land/sea boundary is particularly exposed to high rates of change. Climate warming and sea level rise are claiming coastal land and forcing shoreline change as weather, tides, and sea level impinge on coastal habitats. The land subsidence and sea level rise interaction is causing erosion rates of 1 foot per century within Chesapeake Bay, which is as great as any on the East coast (Ward et al. 1989). Within the lifetime of people, beaches, islands and shores in Chesapeake Bay have completely disappeared, with some accretion also occurring (table 2). Coastal counties with marshland (table 2) and most protected areas with a shoreline (Hahn 1989) show high rates of erosion.

The Delmarva Peninsula is an example of the

Table 2. Chesapeake Bay coastal counties. Population increase categories: low = 0-24; moderate = 25-49; high = 50-74; extreme = 75-99 Sources: 1. Ward, et al. (1989) for erosion evaluation; Field et al. (1991) for wetlands average; Year 2020 Panel (1988) for population increase. Hahn (1989) for protected arears

County	Erosion Evaluation (range)	Wetlands (aceage)	Pop. Increase 1990-2020(%)	Protected Areas
VIRGINIA				
Northampton	Slight, Moderate	98,000	decline	Fisherman's E. Shore
Accomack	Slight, Moderate	105,900	decline	
Northumberland	Slight-high	4,500	low	
Lancaster	Slight-high	3,900	moderate	
Middlesex	Slight-high	5,800	moderate	
Mathews	Slight-severe	5,100	moderate	
Gloucester	Slight-high	12,200	high	
York	Slight-high	5,400	low	Plum Tree York River
New Port News	Slight-high		low	NN City Pk
Norfolk	Slight		moderate	
Virginia Beach	Slight-high			Seashore SP
MARYLAND				
Sommerset	Slight-severe	80,500	low	Pocomoke Irish Grove Martin Cedar Is.
Wicomico	Slight-high	36,900	low	Pocomoke
Dorchester	Slight-severe	156,400	low	Blackwater Elliott Is. M Fishing Bay
Talbot	Slight-severe Accretion	15,500	low	
Queen Anne	Accretion Slight-moderate	29,300	moderate	Tuckahoe
Kent	Accretion Slight-severe	14,400	low	Neck Island
Cecil	Accretion Slight-Moderate	7,500	low	Elks Neck
Harford	Accretion Slight-moderate	12,300	low	
Baltimore	Accretion Slight -moderate	4,700	low	Valley SP Gunpowder
Anne Arundel	Accretion. Slight-severe	16,000	low	Calv. Cliffs Smithsonian
Calvert	Slight-moderate	11,900	high	
Saint Marys	Accretion Slight-moderate	13,500	moderate	S.M. River Pt. Lookout

process of landscape change. The Virginia Coast Reserve, a 110 km of sea margin, is owned and managed by The Nature Conservancy. It is also a National Science Foundation long-term ecological research site. Studies there show that the sea is reclaiming land at a rate of 5 meters per year at one end while accreting at a similar rate at the other end in an active process of erosion and redevelopment of landscape. If rates of sea level rise occur as high as predicted from global warming scenarios (International Governmental Panel on Climate Change,1991, Schneider et al. 1992), the reserve on the barrier island's seaside could be reclaimed by the sea by as much as 9-13 meters of land per year (Ray et al.1992). This change will greatly alter the character of the landscape and the nature of the reserve (Hayden et al. 1991).

Thus, in this active coastal zone, shoreline change is a natural process. Habitats decay and rebuild, appearing to roll over and around the land-seascape to build new marshlands in decades and centuries of time. As habitats rebuild in new locations, estuarine species need to find suitable habitats to sustain their needs. These interactive processes occur over a continuum of change to conserve ecosystem function and maintain estuarine productivity .

Human activities over the entire watershed add yet another level of complexity. Human uses, such as development of reservoirs and irrigation, surface water diversions, and land use within the 64,000 sq. mi of the Chesapeake Bay watershed alter the amount, quality, and rate of fresh water and sediment entering the Bay. Sedimentation rates, anoxia, and eutrophication have increased since the time of European settlement, according to stratigraphic records and a reconstructed 2,000-year history of anoxia and eutrophication in Chesapeake Bay (Cooper and Brush 1991). Changes in freshwater and sediment flows affect salinity patterns and the distribution of habitats and species, including oyster reefs, forcing change to occur on shorter time scales than natural. Disruption of freshwater flows can exacerbate the rate of coastal erosion, the rate of sea level rise, and rate of habitat loss (Shagian et al. 1994). As salinity zones change, the biogeographic patterns across the watershed may also change, affecting the response of habitats and species. Watershed habitats and species may become pinched even more when they encounter the solid edifices built by humans against change.

Natural resource managers will increasingly be forced to confront these changes, as well as to anticipate the impacts of growing human populations. The 64,000 sq mi watershed of Chesapeake Bay now contains 13.6 million people. The population is predicted to grow to more than 15 million by the year 2020, with some coastal counties expecting a population increase of 75% - 99% (Year 2,020 Panel 1988). Public, domestic and commercial water consumption will more than double by the year 2020 (U.S. Army Corps of engineers. 1984). This removal of water from the estuarine system for human purposes will further alter flow rates and water quality, quantity, and timing. As flow rates vary among years, under dry-year conditions human consumption will produce freshwater deficits. In years of severe droughts, the water deficits could have catastrophic consequences for fish and wildlife. Furthermore, the water returned to the system will be used and degraded. Thus, the increasing human population, accompanied by increased affluence (measured in terms of use of hydroelectric power and other conveniences that require water) and new technology that will increase the rates of consumption, will increasingly lower the volume of water returned to the system.

CONCLUSION

Sustainability of natural resources is a widely discussed goal. It is a concept that places science, management, and the public at the forefront of debate (Ecological Society of America 1993). Ludwig et al. (1993) give evidence of historical resource exploitation and the difficulties of achieving scientific consensus concerning resources and the environment. They suggest that wealth or the prospect of wealth generates political and social power that is used to promote unlimited exploitation of resources. Further, they suggest that the complexity of the underlying biological and physical system precludes a reductionist approach to management, as large levels of natural variability mask the effects of over exploitation. "Initial over-exploitation is not detectable until it is severe and often irreversible."

The disagreements in achieving sustainability often result from vague definitions and narrowly defined management objectives. Sustainability needs to be directed to "management of systems under uncertainty, to the linkages among physical, biological and socio-economic systems, and to the interface between science and policy" (Levin 1993). Sustainability requires a change in management focus, from one based on yield to one focused on input (Odum 1989). The management goals of sustainability should relate the resources and their ecological supports to the watershed scale, with a governance focused on the watershed system as it monitors trends in landscape change.

Sustainability of estuarine resources is built into the estuarine system. Estuaries like Chesapeake Bay are highly uncertain environments. They are constantly responding to environmental forces, seasonal change, and community dynamics, acting over long time periods. Yet, despite their natural variable and uncertain nature, estuaries worldwide are one of the most productive regions in the world. Their productivity is attributable to the complex interactions of hydrology, biology, climate and change that act over a large scale in hierarchical associations and with built-in mechanisms of resiliency and repair. Despite the peaks and troughs occurring at the species level that result from smaller scale fluctuations and environmental disturbances, ecosystem function is conserved. Hence, the structure and function are sustained in the face of change owing to higher levels of controls, connectivity of the watershed system, and the system's ability to recuperate from disturbances.

A watershed focus provides a whole-ecosystem perspective, and freshwater input is an example of an important linkage in the system. Changes in fresh water will affect management goals in the sustainability of target species, the restoration of oyster reefs, and the viability of protected areas. In the longer view, changes in freshwater will affect the function and structure of critical habitats (e.g., oyster reefs), and the resiliency and recuperative capacity of the Bay's system. Furthermore, fresh water provides a mechanism for ecosystem accounting, a kind of common currency with which to measure human impact. It connects the people to the Bay's resources and the resources to the people. Freshwater flow and salinity zones are important environmental mechanisms in the watershed system and important to the protection, sustainability, and management of valued species and habitats, (i.e., to the protection of the Bay itself).

In conclusion, the Chesapeake Bay provides an opportunity to examine watershed management in the protection and restoration of estuarine resources. A watershed and freshwater focus provides managers with a perspective on resource sustainability that is otherwise lost in a complicated system of governance that matches the complexity of the estuarine system (Hennessey 1994). While the Chesapeake Bay Program has been successful in achieving necessary agreements (Hennessey 1994), its success is dimmed by the declining trends in key estuarine species, suggesting a misalignment between governance and the management needs in resource protection and recovery. The discontinuity between governance and protection results when the products of ecosystems are managed for their ecosystem endpoint production while they are being isolated from their environmental supports and squeezed further when the natural system seeks to recover from disturbance. Human activities over the watershed are altering the natural structure of the system; human impacts and disease are reducing valued species such as oysters; habitats such as oyster reefs are degenerating and losing ecosystem function; and environmental inputs, such as freshwater, are being altered. Environmental inputs at the scale of the watershed provide important links to resource management and should be managed with the resource in a watershed perspective.

Alignment of governance with resource needs places politics at the center. Hence, alignment requires public understanding. It requires connecting people's habits to the resources that people value and gaining the necessary political support for whole watershed management. Public understanding may be facilitated when common currencies such as fresh water are shown to connect the people to the sustainment of valued resources and habitats. Valued resources such as oyster reefs and valued protected areas need to be promoted for their full worth and vulnerability. They help flag the public's attention and serve to indicate loss of ecosystem function, as they help monitor management success across the watershed system.

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Habitat Restoration: A Framework for Chesapeake Bay

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Abstract: The decline of Chesapeake Bay fish and wildlife as a result of habitat degradation and destruction, and overharvesting, has been well documented. Significant efforts under the Chesapeake Bay Program are directed to restoring ambient water quality conditions for living resources. Recently, the program has recognized the need to restore site-specific habitats, realizing the potential role habitat plays in abating pollutants in addition to providing shelter, food, and travel corridors for fish and wildlife. The program has charged the Living Resources Subcommittee and Habitat Objectives and Restoration Workgroup (HO & RW) to develop "a strategy to integrate and focus on restoration activities."

We present the initial results of the workgroup's efforts toward meeting that charge. The draft strategy, referred to as a "framework for action," outlines a three-phase process. Phase I will facilitate prioritization and funding of current restoration projects, identify and promote research needs, and establish necessary monitoring via existing program structures and plans. Phase II will develop a process for targeting habitat restoration projects within a landscape framework based on the needs of select species, and relying on GIS technology. Phase III will expand partnerships throughout the watershed and integrate innovative projects and joint funding opportunities.

INTRODUCTION

The Chesapeake Bay and its watershed have undergone vast changes since European colonization. Several hundred years ago the watershed was 95% forested, contributing to clean waters and expansive habitats. Nearshore waters contained more extensive saltwater and freshwater tidal marshes used heavily by waterfowl and colonial waterbirds. Shallow waters maintained abundant and diverse oyster reef that played a significant role in filtering Bay waters and offering refuge to myriad species. Agriculture, urbanization, and a burgeoning population, now estimated at 13 million people, have dramatically altered the landscape. All aquatic and terrestrial habitats within Chesapeake Bay have been partially displaced or degraded by development, compromising the ability of these areas to maintain their functional values to civilization and to the fish and wildlife resources reliant upon them. Certain habitats — wetlands, streams, and riparian corridors — have been directly and acutely affected by clearing, agriculture, and urban and suburban development; others, such as submerged aquatic vegetation beds and aquatic reefs, have been indirectly impacted by these pervasive forces across the landscape, and by the direct influences of coastal development and overharvest (figure 1.) Still others, such as Bay islands and some salt marshes, are declining primarily due to natural processes such as sea level rise, shoreline erosion, and regional subsidence.

The Chesapeake Bay Program (CBP) has provided leadership in the development of a nutrient reduction program, principally through the 40% nutrient reduction goal and associated tributary strategies. These efforts are expected to improve ambient conditions of aquatic habitat. Site-specific habitat restoration efforts in the

Chesapeake Bay watershed have been opportunistic and uncoordinated, through a variety of different agencies and funding sources. The need to protect existing habitats and to restore degraded or displaced habitats is overwhelming. Consequently, the Chesapeake Bay Program has established a strong commitment for development of a comprehensive habitat restoration plan: *(1)*"Provide for the restoration and protection of living resources, their habitats, and ecological relationships" (Chesapeake Bay Agreement, 1987). (2) "develop a comprehensive habitat restoration management plan to achieve the goals of the 1987 Bay Agreement and the 1992 amendments which would benefit the maximum number of species: commercial, recreational and ecologically valuable ones alike." (Ecologically Valuable Species Strategy, 1993). (3)"Develop an ecologically-based Habitat Restoration Strategy by July 1994, recognizing the importance of restoring and protecting key habitats for Chesapeake Bay living resources, building strategically upon Chesapeake Bay Program priorities, and integrating existing habitat strategies and implementation plans." (Executive Council's Principal Staff Committee, 1993)

This strategy, entitled "Chesapeake Bay Habitat Restoration: A Framework for Action" (Famework), is a result of these commitments. The framework outlines a process for the development of a coordinated restoration effort in three concurrent phases: **Phase I, II, and III** (figure 2). Many of the policies, plans, and strategies developed by the Living Resources Subcommittee (LRSc) either refer to or specifically require action on habitat restoration. This Framework does not supplant these efforts nor change the individual implementation strategies. Rather, it provides a foundation for integrating the habitat restoration actions in these plans.

Habitat restoration is presented here as a tool for recovering some of the losses described in figure 1. Restoration opportunities in Chesapeake Bay span bottom-up (e.g., restoring water quality for zooplankton communities) and top-down (e.g., restoring habitats needed by colonial nesting birds) approaches. In addition to the activities identified by this Framework, there is an assortment of restoration opportunities that can be addressed by a variety of programs, organizations, and agencies. Restoration activities, however, will never outpace losses resulting from continued development and degradation. Protection and conservation efforts are critical for the restoration of the Chesapeake Bay ecosystem. Protection and management of these systems will require continued advances in point and nonpoint source abatement, acquisition and incentive programs for key buffer areas, and regional development plans that incorporate protection of aquatic systems as a priority goal.

- 1.8 million acras of wetlands lost scince the 1780s.
- At least 50% of riparian wetlands degraded or impacted.
- 62% coverage of SAV in areas of historic (1971-91) occurrence.
- 98% decline in oysters since 1870.
- Over 2,500 barriers to fish passage.
- Bay island erosion rates of 1.5 to 31 feet per year.

Figure 1. Habitat trends in the Chesapeake Bay watershed.

HABITAT RESTORATION STRATEGY

Phase I. Support Existing Restoration Efforts

Phase I will provide information on the status of existing CBP restoration projects within current CBP structure and plans, and identify potential restoration opportunities (figure 3). The CBP has begun to restore water quality and key habitats in the Bay, having established specific goals for several habitat categories (table 1). Other CBP initiatives like zooplankton indicators and benthic goals development, as well as the recommendation of the fisheries management plan taskforce to incorporate habitat into the fisheries management plans, will be incorporated into sections of this strategy.

The CBP began funding habitat restoration projects in 1992 with the funding of artificial oyster reefs in Maryland. In 1993, the CBP funded the removal of 5 blockages for fish passage and provided seed funding for using dredged material to rebuild island habitat on Poplar Island and Bodkin Island. In 1994, CBP expanded the scope of habitat restoration funds, including funding two more passages, design for a third passage, seed money for desiging a fishway at Little Falls dam, continued funding for Poplar Island, aquatic reefs in Virginia and Maryland, and various wetland, riparian, and stream bed restoration projects.

Figure 2. Habitat restoration framework.

Figure 3. Phase I mineral targeting.

For future funding under Phase I, annually the HO&RW will review all candidate projects submitted for consideration and funding, and periodically report project status to the LRSc. Final proposals will be evaluated in light of other plan priorities (e.g., Aquatic Reef Plan and Fish Passage Plan) and overall proposals will be evaluated using the criteria below. High priority projects meeting the guidelines will be forwarded to the LRSc during preparation of the annual budget.

The HO&RW proposes to use the following criteria to evaluate proposals annually. These criteria will allow a comprehensive review of the relative strengths and weaknesses of each project and will give preference to the best overall projects.

- Relationship to Bay Program Habitat Priorities. The project proposes to restore a habitat associated with the priority habitat areas in the Habitat Restoration Strategy (freshwater tributaries and streams, shallow water, open water, inlands and islands).
- Species of Concern. The project addresses a significant habitat need related to a species of concern: anadromous and juvenile fish, shell fish beds, crabs, and migratory birds, in addition to endangered and threatened species or CBP's "Ecologically Valuable Species."
- Adequacy of Design. The project proposal adequately documents the feasibility and effectiveness of techniques intended to address specific habitat restoration need, relying on non-structural techniques.
- Integration with other priority projects or programs. Extent of which the project proposal is part of an existing comprehensive and integrated proposal (i.e., projects are incorporated into a watershed or tributary planning program).
- Cost-effectiveness. The project meets program objectives in the most cost-effective manner.
- Implementability. The project can be implemented in a timely manner.
- Management. The project has a maintenance and monitoring component.
- Model. The project is useful as a model for future habitat restoration projects.
- Cooperation and Support. The project is supported by other public agencies, landowners and other parties necessary for long-term success.

Phase II. Targeting

Targeting Approach

While the restoration of individual habitats based on the criteria and programs identified in Phase I is important in the short term, it is impor-

Table 1. Chesapeake Bay Program habitat restoration goals.

Habitat Type	Goal
Open Water	40% Reduction in Nitrogen and Phorphorus by Year 2000
Wetlands	Near-term no net loss and long term net gain
Submersed Aquatic Vegetation	114,000 acres by Year 2005 under current recovery rates
Aquatic Reefs	10,000 acres by Year 2000 (draft goal)
Fish Passage	1,357 miles spawning habitat open by Year 2005
Forest/Riparian	In development
Beneficial Use Dredge Material (Bay islands & marshes)	In development

tant to develop a system that better targets restoration efforts based on the needs of the living resources. Individual projects can sometimes create and restore one type of habitat at the expense of other necessary habitats (e.g., creating islands displaces shallow water). Also, restoration can be expensive and it is important to consider ways of ensuring that habitat is being restored where it is most needed, with the functions that are most needed.

Phase II targeting will provide a process for guiding project identification through the integration of CBP activities (e.g., linking habitat restoration into the Chesapeake Bay tributary strategies) and developing priorities based on ecological functions and living resource needs (figure 4). Site-specific habitat restoration targeting under Phase II will have three basic components: Data Gathering, Data Analysis, and Restoration Targeting. Data gathering includes the immediate use of existing information on habitat requirements, species and habitat distribution and abundance (maps and atlases), and newly acquired data. Targeting will begin with available non-digitized materials, although such exercises often are tedious.

Varied sources of data and information are essential in building a computer-based GIS designed to facilitate rapid access to comprehensive habitat and species information, while also providing analytical capabilities. Phase II commits CBP to fulfilling, and expanding, its commitment to establishing a GIS. Data "layers" expected to be incorporated into the data base will include: shoreline, tributary watershed boundaries, bathymetry, water quality, submerged aquatic vegetation, wetlands, riparian habitat, stream blockages, land use (urban, agriculture, etc.), species spawning and foraging grounds, oyster beds, anoxic and hypoxic expanses of waters, and other spatial data needed to characterize the watershed and estuary.

Restoration targeting will be achieved best when these multiple data layers can be "over-laid" and analyzed to determine where: (1) indicator species' habitat is most degraded, (2) restoration efforts can benefit multiple species of concern, (3) project feasibility initially can be assessed, (4) costs potentially can be minimized, and (5) intensive targeting can be used to establish models for restoration within select watersheds, particularly as they may relate to nutrient reductions called for in CBP Tributary Strategies. Additionally, based on known habitat requirements, data can be generated to characterize conditions of the water-

Figure 4. Phase II Bay Program targeting.

shed and estuary that are to be achieved to meet restoration goals, thereby providing a "benchmark" or relative measure of restoration success.

While actions under this phase are specific to the targeted habitat area, watersheds which incorporate several targeted habitats and associated actions will receive preference. This emphasis will be reflected in changes to project selection criteria developed for Phase I. Phase II targeting will be used as the cornerstone for building partnerships and networks in Phase III. The following section describes Phase II implementation.

Priority Habitats

To embrace the major habitat types within the context of the Chesapeake Bay watershed, and to complement the CBP strategic priority for habitat restoration, this strategy sets out four separate habitat components and species within each component that will serve as indicators of habitat quality and restoration success: Freshwater Tributaries and Streams, Shallow Water, Open Water, and Terrestrial and Island Habitat (table 2).

For each of the target habitats, the strategy includes sections describing *in more detail* the targeted living resources or life stages, the general habitat needs of these life stages, and restoration goals based on the indicator species needs and the status of the target habitat, pertinent information relative to CBP funding decisions, and priority actions. Salient information and actions needed for each target habitat follows.

Freshwater Tributaries

Migratory fish are excluded from "a major portion" of their historic spawning and freshwater nursery habitats in the Chesapeake Bay watershed due to dams and other obstructions that block spawning streams and riparian areas (Chesapeake Executive Council 1988). Beyond access to spawning areas, the condition of freshwater tributaries and streams is especially important to anadromous and semi-anadromous species because of the sensitive needs of eggs and larval development. Anadromous fish spawn on different substrates, from gravel bottoms to vegetated areas, and consequently restoration activities need to consider access to a variety of substrates. Displacement of expansive forests due to population growth and development has adversely altered the chemical and physical balance of spawning areas. Urban, suburban, and agricultural areas cleared of trees and other vegetation promote increased temperatures through shade loss.

A geographical data base will be the tool used for ensuring proposed projects fall within an area suitable for restoration of anadromous fish spawning areas. This database can be used at first with existing data but should be expanded as new information is developed on habitat requirements, water quality, CBPTributary Strategies, and land use information. The dat base will have to include, at least, all known blockages to the spawning grounds with the status of their removal or fishway construction. Generally, priority will be given to historic spawning grounds with no blockages, or having blockages targeted for removal within 5

Table 2. Target habitats and associated indicator species.

Target Habitat	Indicator Species
Freshwater tributaries & streams	Anadromous and semi-anadromous fish, all life stages
Shallow water	Juvenile fish, blue crabs, colonial waterbirds, SAV, and waterfowl
Open water	Adult fish, aquatic reefs
Forested inlands and islands	Migratory birds

years. As additional information from planned and ongoing stream surveys becomes available, prioritization can be refined. More definitive information is needed on the extent of riparian forests.

Shallow Water Habitat (tidal)

Shallow water habitat, or the littoral zone, consists of tidal wetlands, SAV, aquatic reefs, and unvegetated nearshore critical to many species and life stages of invertebrates, fish, and waterfowl, and the maintenance of trophic interactions. The most significant impact to this habitat over the last several decades has been the loss of expansive SAV beds and aquatic reefs. The organisms of the littoral zone depend upon emergent wetland's, aquatic reefs, and SAV to improve water quality. Since the recent demise of SAV beds and reefs in Chesapeake Bay, many small or juvenile species use primarily shallow water as alternate refuge habitat from larger fish unable to swim in the shallower waters In the absence of SAV, woody debris has been found to be used for refuge for the smaller fish and crustaceans as well.

Similar to the freshwater tributaries and streams, restoration activities aimed at this habitat also will rely on a data base system, much of which has already begun. SAV coverage and the Tier I goal (114,000 acres) and Tier III target (nearshore waters < 2M) have been developed and the Tier II target (nearshore water 1M) has yet to be mapped. Some information on sediment type is in existence but more is needed, and SAV aerial photography could also pick up adjacent marsh, flats, and beach conditions in the areas flown for SAV. Water quality and SAV linkages exist and continue to be refined and projects are under way to develop relationships between the mainstem water quality monitoring program and near-shore conditions. Using this existing information and expanding the information, areas can be targeted for ensuring water quality conditions are being met and that SAV is returning. In areas where water quality conditions are being met but SAV is not returning, transplant pilot projects may be considered. It is essential that SAV monitoring be continued, and that the role of citizen monitoring be expanded.

Open Water (tidal)

Open waters are habitat to key or desirable fisheries species such as striped bass, bluefish, weakfish, American and hickory shad, blueback herring and alewife, as well as to bay anchovy and Atlantic menhaden, two of the three finfish species which presently dominate Chesapeake Bay. Alosid and shad populations are significantly depressed relative to historical levels, whereas anchovy and menhaden are typically more abundant. Habitat degradation/losses and fishing pressure appear to be jointly responsible. Summer dissolved oxygen conditions are presently marginal or unsuitable for fully supporting living resources the entire length of a number of tributaries (Living Resources Habitat-based Water Quality Restoration Priorities, CBP 1993). Overall, the trophic link between phytoplankton and zooplankton has been altered from historic conditions. Much of the carbon generated by phytoplankton is tied up in the very small pico-phytoplankton, which typically enters the microbial foodweb (microbial loop) rather than passing up higher trophic levels of the food chain. Densities of zooplankton in many tributaries are insufficient to support normal larval growth of striped bass and possibly other pelagic spawners (ICPRB 1993). Positive stock responses to fishing moratoriums or quotas suggest fishing pressure is also seriously distorting finfish community structure in the Bay, and may be disrupting the top-down controls normally imposed on the pelagic ecosystem by carnivorous "game" species.

For open water habitat, the development of tools to link water quality conditions to the living resources is critical, including recent CBP efforts into ecosystem modeling. These tools should include continuation of the zooplankton and phytoplankton indicator studies, ensuring not only connections between water quality and the plankton communities, but also between the plankton community and the fish. Continuing work on an estuarine Index of Biological Intergrity will also give an indication of the condition of the open water for fish habitat. Finally, the geographic data base will be necessary to best site and design aquatic reefs. Locations of existing oyster reefs, bottom conditions, salinity, and depth are all necessary components of this portion of the data base.

Forested Inlands and Islands

Forested inlands and islands are grouped together more for convenience of this strategy than any clear ecological division. Both habitat types, however, are considered of significant importance to migratory birds, particularly neotropical migrants (forested inlands) and waterfowl and colonial nesting wading birds (islands). Forested wetlands continue to decline in spite of efforts to stem losses, and island habitats have been eroding at high rates of loss. Several species of neotropical migrants are reliant on forested wetlands, particularly those along coastal and riverine corridors, and have declined over the past several decades. Colonial waterbirds face continued loss of habitat on remote islands due to the influences of sea-level rise and groundwater withdrawal. Efforts by the CBP to reverse wetland loss have yet to be born out due to the recent nature of implementing actions. Efforts to protect and restore neotropical migrants are best exemplified by the "Partners for Flight Program" initiated by the National Fish and Wildlife Foundation. Restoration of islands has just recently been considered as a priority by the CBP and a variety of regulatory agencies in view of beneficial use of dredge material. The CBP has opportunities to assist by stengthening and supporting efforts to use dredge material beneficially and to emphasize restoration of riparian forested habitats. Related activities include determining the extent of riparian habitats and the extent of forest fragmentation, develop technical specifications for forest restorations, and establish the habitat requirements for select forest dwelling organisms.

Phase III. Expand Coordination

In this phase the CBP will aim to integrate restoration programs, mitigation activities, and enforcement actions throughout the Chesapeake Bay watershed to maximize ecosystem benefits (figure 5). (Mitigation requirements will not be funded through the CBP, but CBP funded restoration projects placed adjacent to mitigation sites may be an innovative means to enhance ecosystem benefits.) This will be performed through workshops providing information on funding opportunities and constraints, mitigation and enforcement restrictions, and exploring ways to enhance cross-program opportunities. During this phase, the Phase II database will be made accessible to these various entities.

Many habitat restoration and water quality programs exist in the Chesapeake Bay watershed. While some of the programs concentrate on single components in the landscape (e.g. wetlands and riparian zones), the trend for the future is to formulate watershed management plans that will improve water quality, restore and protect habitats, create land use development criteria and enhance the quality of life for all communities. Watershed management plans currently established and in some stage of operation include the Anacostia

Figure 5. CBP targeting and multi-program coordination.

River Watershed Six Point Action Plan, the Lackawanna River Citizens Master Plan, the Maryland Targeted Watershed Program, and the Potomac River Watershed Visions Project.

While these watershed management programs continue to be established within the larger Chesapeake Bay watershed, no mechanism is currently in place to track programs, progress, methods, extent of habitat restored, or success of those programs and projects. Habitat restored due to compensatory mitigation or other legal decisions likewise are not consistently tracked. The process of combining the financial and technical assistance available through established federal and state programs, land trusts and private organizations is laborious, time-consuming and generally takes an influx of funds. It is not surprising that there are very few existing or proposed restoration projects at the local or private level. An integral part of this phase of the habitat restoration strategy is to establish a program that will integrate these needs with established programs within the targeting framework identified in Phase II.

Unlike the nutrient reduction efforts within the Chesapeake Bay Program, which are funded in large part through partnerships between EPA and the states, there are only limited opportunities for funding habitat restoration activities through these partnerships. However, many other Federal agencies with resource management mandates can fund these activities. Therefore, to be successful at restoring habitats in the Chesapeake Bay one of the most important steps is the development of partnerships for funding, expertise, and information services. Phase III expands the Chesapeake Bay habitat restoration program to provide a mechanism for this partnership to occur.

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Toward a Sustainable Watershed: The Wetlands Landscape Analysis Project

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Abstract: Wetland ecosystems support a variety of species entrusted to the U.S. Fish and Wildlife Service (FWS), including migratory birds and fish. For the FWS to effectively carry out its mandate under federal law to sustain viable populations of fish and wildlife dependent upon wetland eco-systems within the Chesapeake Bay drainage basin, a proactive approach to land management is needed.

Attempting to restore and manage sustainable landscapes requires an understanding of the relationships between ecosystems, the effects of changes in spatial patterns on ecosystem processes, and the role of anthropogenic disturbance. In 1990, the FWS initiated the wetlands landscape analysis project in the Chickahominy River watershed, south-central Virginia, to test the viability of the landscape approach to wetlands conservation in the Bay watershed.

The method applied in this project will identify and quantify cumulative impacts throughout the Chickahominy River watershed to provide a reference point for refining existing management activities and developing new management strategies based on a landscape orientation. Changes in landscape structure (e.g., proportion of land cover types, contagion, fractal dimensions, patch size) will be quantified and used to determine the effects on landscape function. Landscape function has been categorized as consisting of three components: biotic diversity, hydrologic dynamics, and water characteristics.

An important characteristic of this project is that it is not an FWS owned project. To achieve the goal of the project, partnerships at all levels of government and the private sector are needed. A synopsis of existing partnerships and their structure is discussed in this paper.

INTRODUCTION

A common theme throughout the Chesapeake Bay watershed is the continued conversion and degradation of wetland ecosystems (Tiner 1987, Tiner et al. 1994). Disturbances resulting from an increasing human population that refuses to comprehend limits to its quest for the “good life” are both obvious and insidious. The effects on wetland systems stemming from human activities exacerbate nonanthropogenic disturbances that were once the primary driving force shaping wetland ecosystem structure and function. Effects on wetland ecosystems can accumulate temporally and spatially as the result of disturbance mechanisms (Preston and Bedford 1988), and are often triggered by disturbances beyond the wetland system. These effects may be adverse, and result in “cumulative impacts.” Because cumulative impacts occur over space and time and do not necessarily originate within a wetland, efforts to identify and interpret such phenomena require landscape-level analyses (Gosselink and Lee 1989).

In the last 20-plus years, numerous laws, regulations, and policies have been enacted, adjudicated, and implemented to conserve wetlands, often with much accompanying controversy and continued wetland conversions. Site- or system-specific, species-specific, and agency-specific perspectives and policies have resulted in fragmented wetland systems and fragmented decision making capabilities affecting wetlands conservation. A comprehensive approach that addresses the wetland ecosystem as part of the landscape in which it is embedded is presently lacking. Our decision making processes require the same landscape connectivity that is reflected by the linkages between wetland, terrestrial, and aquatic ecosystems. In 1990, the U.S. Fish and Wildlife Service (FWS) initiated the Wetlands Landscape Analysis Project in the Chickahominy River watershed, south-central Virginia, to test the viability of a landscape approach to wetlands conservation in the Bay watershed.

METHOD

The management and restoration of sustainable landscapes requires a scientific understanding of the spatial relationships between ecosystems, the functional linkages between ecosystems, and the sources and effects of disturbance on ecosystem pattern and process (Turner 1989). It also requires an analysis of the socioeconomics of that landscape to understand what is driving the anthropogenic disturbances affecting landscape structure and function. The Wetlands Landscape Analysis Project approach is based upon analyzing variables of spatial pattern and landscape function as the primary "screen" to address cumulative impacts through time. Information at smaller scales (e.g., habitat), together with species life history information, will also be incorporated into the analyses. Specifically, the project approach will

- identify indicators of landscape structure;
- quantify changes in landscape structure over time;
- identify indicators of landscape function;
- quantify changes in landscape function;
- determine the relationship between wetland, terrestrial, and aquatic ecosystems within the Chickahominy River watershed relative to landscape structure and function, and changes to landscape structure and function over time;
- conduct analysis of historic, current, and projected economic and cultural patterns relative to land use throughout the watershed; and
- use the results from the socioeconomic analysis and the temporal and spatial landscape results to refine existing management actions and develop new land stewardship strategies that are oriented at the watershed level.

Figure 1 provides a conceptualization of the approach that will be tested in the Chickahominy River watershed. The socioeconomic component of the approach is still under development. This paper focuses, therefore, on the landscape structure and function components of the approach.

Landscape Structure

To understand the relationship between changes in spatial patterns throughout the Chickahominy River watershed and the effects of those changes on landscape function, measures of spatial pattern, or **landscape structure**, will be identified and quantified over time. Turner (1990, 1989) identified several measures of landscape structure, including proportion of total landscape area by each landcover or landuse type (P_k), fractal dimension of patch perimeters (d), relative richness (R) and evenness (E), diversity index (D), and patch size (s) and contagion index (C).

Initial analyses will consist of interpreting 1994 NAPP CIR and 1950s or 1960s black and white aerial photography of the Chickahominy River watershed using nine land cover and land use categories, developing a digital land cover and land use data base in PC ARC/INFO format from the interpreted photography, and quantifying several landscape structure variables for both time

Figure 1. Conceptualization of cumulative impact analysis, in the Wetlands Landscape Analysis Project.

periods using the digital data. Differences between the variables measured will be compared and determined whether they are significant. Variables that will be measured include P_k, s, C, R, E, D, and perimeter:area-to-ratios. In addition, local comprehensive plans and zoning information will be used to develop models to predict potential future changes in landscape structure.

Landscape Function

The ecological linkages between different ecosystems within the Chickahominy River watershed will be investigated and combined with those from the landscape structure analyses to address cumulative effects to landscape function. **Biotic diversity, hydrologic dynamics, and water chemistry** represent three components of landscape function used in the wetlands landscape analysis approach.

Aspects of each functional component will be examined through interdisciplinary investigations. Variables representing hydrologic dynamics (e.g., surfacewater and groundwater hydrograph data), water chemistry (e.g., nutrients, pH, and total suspended sediments), and biotic diversity (e.g, keystone or indicator species such as amphibians, forest- interior breeding birds, invasive plant species, or rare vegetation communities) will be examined simultaneously. Where simultaneous investigations are impractical or impossible, consecutive investigations focusing on ecosystem linkages will be undertaken. In this manner, inter and intra-ecosystem process pathways that reflect landscape function can be addressed.

Members of the watershed technical committee (see below) are currently developing a 3-year interdisciplinary research proposal that may involve investigating the linkages between ground water movement and chemistry, amphibian distribution and composition, and wetland vegetation community diversity and what the effects of changing spatial patterns have on these linkages.

While the comprehensive research proposal is under development, the Virginia Department of Game and Inland Fisheries and the FWS have initiated a landscape-level forest breeding bird investigation. Intensive timber management and urbanization in the watershed are disturbances that are likely to adversely affect mature forests inhabited by forest-interior birds through changes in land cover type or through fragmentation effects, such as decreased size of forest interior, increased edge length and width, invasion of weedy plants, decreased soil moisture, and increased predation and parasitism. Forest size has been correlated with bird species composition and richness (Robbins et al. 1989), although the importance of patch shape and adjacency to similar patches, particularly for forest- interior species, is still under investigation.

Mature upland and wetland forests are presently being sampled throughout the watershed for migratory and breeding bird habitat distribution, species richness, and relative abundance. In addition, landscape structure variables (e.g., forest patch size, shape, and contagion) will be measured and analyzed to determine if there is a relationship with the presence or absence of forest breeding bird species.

The historic and current landscape structure data will be used to analyze potential historic changes in forest breeding bird distribution based on present forest breeding bird distribution data, in that historic breeding bird data are lacking. Potential impacts on forest breeding birds resulting from future changes in spatial patterns owing to anthropogenic activities will be investigated through development of predictive models.

The results of this investigation will give us a picture of functional linkages between terrestrial and wetland ecosystems for the watershed. Management for all forest breeding birds can then be addressed comprehensively versus only on a site- or species-specific basis.

An Information Network

In lieu of a general distribution of the results and conclusions from the cumulative impact investigations, an information network is under development. The network is presently organized into three groups:

- A technical committee, represented by academicians and state and federal natural resource professionals.
- A watershed coalition, composed of watershed citizens, local business leaders, local government representatives, special interest groups (historic and cultural preservationists, conservationists, recreationists), and representatives of the technical committee and the interagency forum.
- An interagency forum, composed of local, state and federal agency representatives that make decisions directly or indirectly affecting living resources.

The technical committee is responsible for identifying research needs and funding sources, designing and conducting interdisciplinary investigations, refining the Wetlands Landscape Analysis Project approach, and interacting with the other network groups.

The role of the watershed coalition is to identify mechanisms to apply the results and conclusions from the landscape investigations and work with government agencies and others to ensure that the applications are carried through. The watershed coalition will also serve as the conduit of information exchange between the other network groups.

The interagency forum will identify and implement mechanisms that ensure the conservation of natural, historic, and cultural resources throughout the watershed in a manner that reduces duplication and protects the long-term viability of those resources throughout the watershed.

SUMMARY

There are a variety of activities that disturb wetland ecosystem functioning throughout the Chickahominy River watershed, such as sand and gravel mining, timber harvesting, or construction of impoundments for recreation, drinking water supply, or flood control.

Until we incorporate a landscape approach into our decision making processes, however, we cannot understand the effects of our decisions regarding individual or aggregated activities - whether they incur adverse ramifications that are irreversible (i.e., a critical ecological threshold is crossed) or whether they result in changes to ecological processes that can be absorbed by the dynamic stability of the system.

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WETLANDS IN THE LANDSCAPE: THE PRIVATE MARKET ALTERNATIVE FOR MITIGATION SUCCESS

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Abstract: Two decades have passed since wetlands protection became a central concern of national environmental policy, but debate over the intent and scope of that policy continues. Today, we now agree that some wetlands functions are worthy of protection and even enhancement from current levels. This has led to widespread acceptance of no-net-loss of acreage and function, to be followed by net gain, as the goal of wetlands programs. Toward this goal, we have succeeded in sharply reducing the primary source of wetlands loss—agricultural conversion—in part, through policy action intended to reduce the economic return to wetlands clearing and drainage. Meanwhile, a variety of wetlands restoration programs in federal and state government have been authorized and are operating. Concurrently, and receiving most attention, have been continuing changes to clarify regulatory programs such as section 404 and the associated state programs to ensure that mitigation requirements of the regulatory program ensure that no-net-loss is achieved.

Generally, wetlands regulations require permit applicants to consider alternative developments thatwill avoid the wetlands. However, if a permit is granted, compensation for the filled wetlands is expected by creating wetlands from uplands or by restoring functions to a degraded wetlands area. These compensations are called mitigation credits. The regulatory expectations for receiving compensation are warranted by the goal of no-net-loss. But, no-net-loss can only be realized when compensatory mitigation is spotty, and there is widespread concern among wetlands managers that the no-net-loss goal is not being advanced within the regulatory program. This problem of "mitigation failure" has several sources, each of which is described in the paper.

This paper then explains how the creation of private mitigation credit markets can reduce mitigation failure. The private market alternative, if carefully structured, also offers a competitive economic return on investment to private restoration firms and can expedite the permit review process for land developers. Indeed, the private market opportunity has been recognized by entrepreneurs and wetlands regulators in many areas of the country and actuarially has been implemented in several cases. Meanwhile, across the nation the challenge of creating regulations conducive to such markets is being actively discussed at all levels of government, and in the Chesapeake Bay region in both Maryland Delaware.

General recommendations are made that would allow private credit markets to operate to satisfy the goals of regulators, permit applications, and private credit suppliers. Each is described and defended in the paper. These recommendations are: allow advanced credit sales, clarify Contract Conditions, Allocate Liability for Mitigation Failure, using Liability Rules that Reflect Realictic failure probabilities and repair costs, and make regulatory reforms to enhance market trading of wetland credits.

INTRODUCTION AND DISCUSSION

Mitigation credit markets are a special case of "mitigation banking." Mitigation banks are large areas of replacement wetlands created for the express purpose of providing off-site compensatory mitigation for more than one future wetland development project. The vast majority of mitigation banks in operation today are single-user banks; that is, each was developed by a single large public or private developer to provide only for its own future mitigation needs. By contrast, private mitigation credit markets would encourage entrepreneurs to establish commercial mitigation banks from which credits would be sold to wetland developers in need of compensatory mitigation. Such markets could help the nation achieve no-net-loss of wetlands by increasing the opportunity to obtain successful compensatory mitigation for permitted wetland losses.

On-Site Mitigation and Off-Site Mitigation Banking

The "mitigation sequencing" rules of the federal wetland regulatory program require developers (i.e., permit applicants) to first avoid and minimize wetland impacts to the extent practicable, and then mitigate any remaining impacts that cannot be reasonably avoided. Compensatory mitigation is expected in the form of wetlands created from uplands, the restoration of former or severely degraded wetland areas, or by enhancing the functioning of existing wetlands. These compensatory mitigations, which are expected to be constructed on-site (i.e., at the permitted site) if at all possible, are called mitigation credits.

Although federal wetland regulations emphasize the use of on-site mitigation to compensate for unavoidable wetland impacts, the rules provide that the use of off-site mitigation banks may be an acceptable alternative in certain situations. Mitigation banking offers the opportunity to obtain compensation for wetland impacts caused by multiple independent or linear development projects by locating a single, large-scale wetland mitigation project elsewhere in the watershed. Developers favor mitigation banking because it can reduce the costs and delays often associated with the permit review process. Regulators are interested in mitigation banking because of its potential ecological advantages. For example, mitigation banks typically involve large-scale replacement wetlands that can, in many instances, more effectively maintain ecosystem function than isolated on-site mitigation projects.

Despite the potential of off-site mitigation banking to increase the efficiency and effectiveness of wetland regulation, its use to date has been very limited. This is because traditional single-user banking arrangements are necessarily limited to those large public and private developers that routinely undertake many independent or linear development projects and can afford a substantial up-front investment in compensatory mitigation. In addition, regulatory and resource agencies often have been reluctant to endorse mitigation banking because of the perception that it may lead to "buying" permits.

Private versus Public Credit Markets

Mitigation credit markets offer the opportunity to increase the efficiency and effectiveness of compensatory mitigation by providing the banking option to a wider set of permit applicants. Indeed, toward this end a number of states and localities across the nation have established public commercial banks and public fee-based mitigation systems (sometimes referred to as "in-lieu" fee systems). Public commercial banks offer mitigation credits for sale to the general public, and use the proceeds from credit sales to recoup the costs of bank construction and management. Similarly, public fee-based systems charge permit fees for projects involving small wetland impacts in lieu of the direct provision of mitigation by permittees. Fee revenues are accumulated in trust funds for the intended future provision of replacement wetlands by the government entity.

Although the broader establishment of these two types of public mitigation systems could potentially extend the advantages of mitigation banking to a wider set of permit applicants, important obstacles must first be overcome. One major problem for establishing public banks involves the substantial up-front public financing needed for bank construction and management. Public fee-based systems may also face financing problems in that there is no guarantee that fee revenues accumulated in trust funds for replacement wetlands will not be diverted to other uses.

Unlike commercial mitigation banking by public entities, a private credit market system would tap the profit motive to encourage private entrepreneurs to produce mitigation credits with private capital. If entrepreneurs emerge to sell credits to many possible buyers, a private market for wetland functions would develop. Market competition could ensure that mitigation credits were provided at least cost, and provide incentives for the further development of wetland restoration technologies as credit supply firms seek out more successful mitigation techniques.

The Benefits of Private Credit Markets

The most obvious benefit from private credit market systems is the opportunity to secure mitigation for the many small wetland impacts that would otherwise go unmitigated. For example, under general permits, including Nationwide 26 permits, compensatory mitigation is often not required when wetland alterations are so small that the possibility of on-site mitigation is deemed impractical or infeasible. The cumulative impact of many such small wetland losses is one cause of slippage from the no-net-loss goal. The widespread establishment of private credit market systems could correct this deficiency by making credits available for sale in small increments. Regulators could then require compensatory mitigation in cases involving small wetland impacts by having developers purchase equivalent credits from established private commercial banks.

Credit market systems could also have broader application to permitted development projects involving more significant wetland impacts. Current wetland regulations emphasize the on-site mitigation option in the hope that important site-specific wetland functions, such as stormwater retention and erosion control, will be retained at the site affected by the fill activity. However, wetland development projects also impact wildlife habitat and ecological "life-support" functions that may be transferable to other locations within watersheds.

The opportunity to successfully replace lost habitat and life-support functions may often be improved by conducting mitigation away from the development site. For example, in some instances the inflexibility in the mitigation sequencing rules of the regulatory program—which require permit applicants to avoid, minimize, and mitigate wetland impacts on-site—may limit the possibility of successful mitigation. This can occur if permitting decisions pay too little attention to the possible fragmentation, isolation, and functional degradation of the preserved wetlands and replacement wetlands provided by in-kind and on-site mitigation.

Allowing the purchase of private market credits in certain cases, instead of requiring on-site mitigation, could also enable regulators to avoid the several institutional sources of failure associated with on-site mitigation. Foremost among these are problems of enforcement:

- When permits are granted conditional on the provision of mitigation, typically "on-site and in-kind." often no compensation effort is ever made.
- If mitigation is initiated, regulators often do not have the technical expertise nor the time to check the mitigation plans for technical quality and feasibility or to check the construction practices which execute plans.
- Often there are too few resources to allow for regulatory monitoring of mitigation projects that are constructed.
- If a mitigation project is monitored and determined to have failed, there may be no responsible party liable for rectifying that failure.
- If a mitigation project is constructed and judged successful in the short term, often there is no assurance that the mitigation site will be maintained as a wetland into the future.

The credit market alternative could greatly reduce the institutional and ecological sources of on-site mitigation failure inherent in the current regulatory program by leading to the following outcomes:

- Private credit markets would tap and combine mitigation expertise, planning, and capital in a manner that is typically not possible with on-site mitigation projects. Then if a permit applicant had the option of buying credits from an established bank that had already planned for and provided replacement wetlands, there would be less chance that the permit applicant's compensatory mitigation requirement would go unfulfilled.
- The consolidated mitigation projects provided by private banks would enable the regulatory agency to concentrate its limited oversight and monitoring resources on a much smaller number of mitigation sites.
- Regulators would have more leverage and a greater variety of tools for imposing cost liability for mitigation failure in the banking option in that regulators could dictate the conditions under which banks could be utilized.
- Private banks would reduce the problem of ecologically vulnerable mitigation sites by consolidating what would otherwise be many isolated and fragmented on-site mitigation

projects into a relatively few areas of replacement wetlands that could be sited and constructed according to watershed goals.

- The increased likelihood of successful replacement wetlands and available mitigation credits would make the evaluation of permit applications more focused on issues concerning the need for the permit and the ecological value of the impacted wetland if the permit is or is not granted. These important permitting issues would then be divorced from concerns about the possibility and likelihood of successful mitigation.

Indeed, these advantages have been recognized by entrepreneurs and wetland regulators in many areas of the country, and two private commercial mitigation banks—the "Millhaven Plantation Bank" in Screven and Burke Counties, Georgia, and the "Florida Wetlandsbank" in Pembroke Pines, Florida—have already obtained federal permission to create and sell mitigation credits under the Section 404 regulatory program. Moreover, across the nation the challenge of creating regulations conducive to private credit market systems is actively being discussed in a number of states and localities.

Necessary Conditions for the Emergence and Success of Private Credit Markets

The two newly permitted and a dozen or so prospective credit suppliers (i.e., private commercial bankers) across the country were interviewed as part of this study. They expected a strong demand for this alternative way of satisfying mitigation requirements provided that it could be made acceptable to regulators and resource agencies. The study interviews generally suggest that a ready supply of mitigation credits would emerge from entrepreneurs in many areas of the country provided that the conditions for market operation established by regulators enabled credit suppliers to earn a competitive return on investment.

But wetland regulators have legitimate concerns about whether the bank mitigation projects from which credits are sold will succeed over time. The emergence of the private market alternative and its ability to improve the effectiveness of compensatory mitigation depend on the capacity of regulators to fashion trading and regulatory rules that provide enforceable environmental safeguards without being cost-prohibitive.

The report on which this paper is based (see note at end of paper) describes in detail the types of trading and regulatory rules that could be used to promote the establishment and use of private credit market systems to simultaneously satisfy the goals of regulators, permit applicants, and private credit suppliers. Its conclusions and recommendations for facilitating the emergence and success of private commercial banking center around seven major themes:

1. **Allow Early Credit Sales**. Regulator concerns about allowing the use of private credit markets to satisfy mitigation requirements center around the risk of mitigation failure. This concern may tempt regulators to require private commercial bank mitigations to be in place and fully functioning before they could be used as compensatory mitigation. Use of this risk-minimizing strategy in the credit market context would force private banks to bear the full costs of waiting for the maturation of replacement wetlands (i.e., opportunity costs of invested capital) as well as all failure risk costs. However, these costs would probably be too high for most private commercial mitigation banks to earn a competitive return on investment. If a market-based trading system is to operate, there must be opportunities for private banks to sell credits before replacement wetlands reach functional maturity or self-maintenance, and in some cases, perhaps even at the time mitigation is initiated. This would be consistent with the regulatory conditions placed on traditional single-user banking arrangements. Early credit sales may be warranted when the bank site and mitigation expertise are favorable for mitigation success, and bank rules have been established to limit failure risk and allocate cost liability for failure.
2. **Establish Bank Standards for Performance, Monitoring and Maintenance, and Long-Term Management**. Regulators must clarify in advance the "contract" conditions for credit suppliers in "memoranda of agreement" and/or regulatory permits. The agreements recorded in these contracts should specify (in addition to bank siting, design, and construction specifications) performance standards that define the conditions under which mitigation projects would be judged successful; monitoring and maintenance requirements to detect and correct deficiencies and; provisions to ensure long-term site management. Performance standards should provide some leeway to account for less-than-extreme natural events which might cause bank mitigations to evolve along somewhat different paths than originally planned.

3. **Allocate Cost Liability for Mitigation Failure**. In order to ensure mitigation quality control while maintaining the economic viability of private credit markets, regulators should allocate to credit suppliers (or permit applicants) those failure risk costs resulting from nonperformance with contract requirements regarding the design, performance, and management of mitigation projects, but not for extreme events which prevent credit suppliers from fulfilling contract obligations.
4. **Ensure that Liability Rules Reflect Realistic Failure Probabilities and Repair Costs**. There are a variety of mechanisms that could be included in the contracts for mitigation suppliers (or permit applicants) to allocate cost liability for mitigation failure. These mechanisms, which include higher trading ratios, performance bonds, leases with collateral banks, and insurance systems, should be viewed as substitutes for each other whose use could vary by situation. Moreover, the level of risk cost (i.e., financial assurance) established by liability rules in any particular mitigation case must be reasonable in consideration of realistic failure probabilities and repair costs for that case.
5. **Establish Rules for Credit Valuation and Trading**. The establishment of private commercial credit market systems requires that the type and level of wetlands functions and ecological values at the bank site be specified. Only if such a functional assessment is conducted will it be possible to judge how many credits have been created for sale. Bank specific rules should be established for determining how credits will be defined and their level assessed. There are several methods that have been used in mitigation decisions for defining mitigation credits and determining the compensation needed when granting a permit. Current commercial banking experience shows that there are as many ways in which such methods can be used as there are different banks. Additional development of these assessment techniques for all types of permit and mitigation decisions should be expected. In addition, rules are needed to define the types and sizes of wetland development impacts for which credits can be used to provide compensatory mitigation, as well as the geographic service area of the banks. As with credit definition and evaluation, rules defining bank market and service area would necessarily depend on case- and area-specific factors and goals.
6. **Make Regulatory Reforms to Enhance Market Trading**. The benefits of private credit markets would be maximized if a sufficient number of credit supply firms enter the market, making the supply of credits adequate for mitigation needs. To encourage market entry, there must be consistency in the mitigation requirements for banks and on-site mitigation projects; there should be no price controls placed on credits produced by private commercial banks, and the market area over which credits may be sold should not be too narrowly proscribed. In addition, regulatory rules should require full-cost pricing of credits sold by public banks and in-lieu fee systems to ensure that such public mitigation systems do not subsidize wetland development and undercut the private credit market alternative.
7. **Incorporate Credit Markets into Watershed Planning and Management**. If the wetland regulatory program were integrated with regional or local watershed planning initiatives, the feasibility and success of private credit markets could be improved.

NOTE

This paper is an executive summary of a report that describes commercial mitigation credit markets as a mechanism to (1) reduce permitting delays, (2) ensure mitigation success, and (3) offer a new profit opportunity for private entrepreneurs in environmental management. At the time of this writing, there is a rapidly expanding interest in commercial credit markets, and a number of suppliers have already entered the business and begun selling credits. There is also increased willingness by regulators and resource agencies to use these suppliers within the wetland permit program whenever the conditions (described in the above summary) can be met. The authors continue to work on the subject of commercial banking, focusing on the potential and limitations of publicly funded commercial credit supply and the potential for wetlands categorization through watershed planning to advance the three goals listed above. For a copy of the report, contact Dr. Robert Brumbaugh, Water Resources Support Center, Institute for Water Resources, CEWRC-IWR-P, 7701 Telegraph Road, Alexandria, Virginia 22310-3868. Phone: (703) 355-3069. Fax: (703) 355-3171 or 8435. For additional information, contact the authors.

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Location and Wetland Values: Some Pitfalls of Off-site Wetland Mitigation in the Chesapeake Watershed

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Abstract: As the focus of resource management broadens to the watershed level, policy-makers are being forced to deal more explicitly than ever before with ecological/economic trade-offs and with comparisons of relative risk. Decisions to protect one watershed feature often transfer ecological threats, (e.g., industrial development) to some other resource or some other part of the watershed where they may have more serious consequences. Decisions to dedicate money and political capital to protect or restore one feature of the watershed leaves less for other initiatives that may be more important or more urgent. In complex ecological/economic systems like the Chesapeake watershed, such trade-offs are difficult to analyze, but are enormously important.

Nothing pressures regulators to make decisions more quickly and more routinely about critical ecological-/economic trade-offs within the Chesapeake watershed than wetland mitigation regulations. These regulations involve a process known as “sequencing”, which allows unavoidable wetland impacts as long as they are mitigated through wetland creation, restoration and enhancement projects. Dozens of times per month, wetland regulators approve mitigation plans that involve swapping important features of the watershed landscape, and with growing frequency shuffling them around the watershed from one location to another.

As a practical matter, the ongoing controversy over wetland mitigation policy centers around the prevailing regulatory preference for on-site mitigation-mitigation as close as possible to the site of the wetland loss. Critics argue that this policy results in relatively small, fragmented, isolated wetlands adjacent to development sites. They point out that these replacement wetlands often provide few environmental benefits and argue that allowing off-site mitigation would provide more opportunities for trading up for selecting mitigation alternatives that provide the greatest ecological payoff at a watershed level. Supporters of on-site mitigation argue that off-site miti-gation, which by definition involves replacing wetlands at one location with wetlands somewhere else, has too many watershed level impacts and also has long-term ecological and economic implications that have not been adequately explored. Here we review some of the near-term and long-term ecological and economic consequences associated with relocating wetlands with special attention to trade-offs between urban, suburban, and rural wetland sites in the Chesapeake watershed.

INTRODUCTION

Historical Mitigation

Wetland mitigation—compensating for the destruction or degradation of an existing wetland by creating, restoring, or enhancing other wetland resources—has long been, and continues to be, controversial. Compensatory wetland mitigation emerged in the 1970s as a way for sponsors of projects with adverse impactson wetlands to obtain wetlands permits they could not otherwise get, by agreeing to undertake activities to offset a portion of those impacts (Want 1993). A deep mistrust of mitigation emerged within the environmental community at that time, because mitigation was not only frequently ineffective, but also often resulted in greater impacts on existing wetlands than would have been allowed in the absence of mitigation.

Permit seekers today must generally demonstrate that a proposed project is in the public interest without mitigation, and also show that impacts on wetlands have been avoided and minimized to the maximum extent practicable before a permit will be issued. Thus, the decision to issue or deny a permit has been separated from establishment of mitigation requirements, and it is harder to argue that mitigation increases conversion of existing wetlands. Nevertheless, mistrust of mitigation and concern about potential abuses of mitigation remains strong within the environmental community.

Mitigation remains at the center of controversy over wetland policy in part because of a poor record of compliance with mitigation requirements, high reported failure rates for mitigation projects that are undertaken, and low environmental value even of superficially successful projects. Limitations of restoration science may account for some historical mitigation failures, but considerable evidence suggests that wetland mitigation's poor record is more a result of institutional and regulatory failures (King 1991, 1992, King and Bohlen 1994a, King and Bohlen 1994b).

A New Focus

In 1988, the National Wetland Policy Forum developed a widely accepted national goal of no net loss and an eventual net gain of wetland resources by acreage and function (Conservation Foundation 1988). This goal has been formally adopted by the Chesapeake Bay Program, included as the explicit goal of Maryland's Nontidal Wetlands Protection Act, and adopted by federal regulators (Chesapeake Bay Program 1988, Maryland Code 1989, U.S. Environmental Protection Agency and Department of the Army 1989-1990). With a clear goal for wetland policy, regulators have been developing rules and policies to improve mitigation practice. At the same time, scientists have been taking a closer look at why mitigation projects succeed or fail and are beginning to tease apart the technical, economic, and regulatory barriers to environmentally sound mitigation policies (Bernstein and Zepp 1990, Crewz and Lewis 1991, Erwin 1991, Florida Department of Environmental Regulation 1991, Harvey and Josselyn 1986, Kusler and Kentula 1989, Race 1985, King and Bohlen 1993, Kentula et al. 1992).

Little attention, however, has been given to the environmental and economic consequences of off-site wetland mitigation—allowing wetland impacts at one site to be offset by mitigation efforts somewhere else. In off-site mitigation wetlands at one location are, in essence, traded for, wetlands somewhere else. When these trades are examined from a watershed or landscape perspective, however, it becomes clear that wetlands at different locations, even if functionally similar, do not generate the same ecological and economic values and do not benefit the same people. These differences in the level and distribution of ecological and economic values associated with wetlands at different locations are the focus of the research summarized here.

On-Site Versus Off-Site Mitigation

Existing regulations and other policies favor mitigation at the site of the wetland impact over off-site mitigation. Cogent criticisms of this approach have been raised, both on environmental and economic grounds (Willard and Klarquist 1992, Shabman et al. 1994, White House Office of Environmental Policy 1993). Environmentally, critics of a preference for on-site mitigation point out that it sometimes results in construction of wetland mitigation projects in questionable locations, such as within highway cloverleaves or in the middle of large commercial developments. Such siting decisions may limit some wetland functions, by all but ensuring the mitigation wetland will suffer from poor water quality, provide inferior wildlife habitat, and offer little in the way of aesthetic, recreational, or educational value. Economically, the preference for on-site wetland mitigation often increases mitigation costs by forcing mitigation in areas where providing appropriate wetland hydrology is difficult and land is expensive.

The controversy over on-site versus off-site wetland mitigation has taken on more importance as interest in wetland mitigation banking has increased. Mitigation banking refers to the practice of using one or more (usually large) wetland creation or restoration projects to provide mitigation for impacts from many smaller wetland impacts. By its very nature, mitigation banking involves off-site mitigation. Thus, issues and trade-offs related to on-site versus off-site wetland mitigation are critical for understanding the long term environmental, economic, and policy implications of the widespread adoption of mitigation banking.

The Urban-Rural Landscape Gradient

In the modern world, human activity alters even the most remote landscapes (McKibben 1989), but some landscapes are affected to a much greater degree than others. Urban areas are more intensively manipulated by humans to achieve economic and social ends than are areas far from urban centers. Rural landscapes, although sometimes shaped in less-direct ways, are no less profoundly influenced by human activity. The notion that urban areas as structured by humans and rural areas are structured by nature ignores the often profound human transformation of landscapes that has occurred even in the most remote rural hinterlands that surround urban centers (Cronon 1991). The rural landscape is not natural, nor is the urban landscape artificial. Both landscapes are the result of an ongoing interaction between human economic and social systems and physical, chemical, and ecological processes. Landscapes and the ecological and human systems of which they are composed change in systematic, if complex, ways as one moves from an urban center, through suburbs, to high-intensity agriculture, through low-intensity agriculture, to non-agricultural forest and wildlands. This urban-rural landscape gradient (McDonnell and Pickett 1990), although often unrecognized by policy makers, in fact underlies and determines the success of much water quality and wetland policy.

Anthropogenic wetland impacts, in particular, are strongly structured by the urban-rural landscape gradient. Wetland impacts in rural areas are driven, in large part, by forestry and agricultural practices; losses in urban, suburban, and resort areas by private and public development activities. Moreover, private development activities in urban-suburban and resort areas are less likely than their rural counterparts to avoid wetland impacts altogether, or reduce impacts to the point that mitigation is not required. Sponsors of more-profitable suburban projects are generally able to afford the transaction costs associated with seeking an individual wetland permit, and in a more developed landscape, avoiding wetland impacts is typically more difficult because of constraints imposed by existing land uses. Thus, individual wetland permits, and associated demand for wetland mitigation, are not randomly scattered across the landscape, but instead cluster in suburban and resort areas and in areas where human activity is generally more intensive.

Wetland mitigation costs also vary along the urban-rural landscape gradient, with higher costs in urban settings and lower costs farther from urban centers. The price of land is typically highest in urban areas, and the costs of some inputs to wetland mitigation projects (e.g., labor, costs for disposal of fill material) also decline as the mitigation site becomes more distant from urban areas. Qualitative differences in project characteristics between urban and rural projects also have a profound effect on total project costs. Urban and suburban watersheds are often degraded by hydrologic modification, as well as by chemical and thermal effects of stormwater runoff. Thus the restoration and creation projects must be carefully engineered and constructed to handle the stresses imposed by the surrounding urban setting. Moreover, many desirable sites in urban and suburban landscapes where wetland creation or restoration would be relatively inexpensive are unavailable for mitigation purposes because of existing or alternative high-value land uses. Thus, urban and suburban mitigation must often be located in second or third best sites, further driving up project costs and risks.

On-site wetland mitigation (by definition) occurs in the same landscape context as the wetland impacts that it is meant to offset. Yet off-site mitigation is unlikely to be distributed across the urban-rural gradient in the same way that wetland impacts are. Individuals, firms, and government institutions have a strong cost-based incentive to construct mitigation in rural settings, even for impacts in urban and suburban settings. Without clear guidance about ecological and economic trade-offs, regulators may perceive that they have little reason to resist replacing urban or suburban wetlands with wetlands in rural areas because both the probability of successful wetland creation or restoration and the overall quality of the resulting wetland are generally thought to increase as one moves from urban to more-natural settings (National Research Council 1992). Thus, expanded use of off-site wetland mitigation and widespread implementation of wetland mitigation banking are likely to lead to significant, unplanned changes in the distribution of wetlands across the urban–rural landscape gradient. The long-term consequences of such a redistribution, even if it does not involve any loss of wetland acreage or function, are not well explored.

Basic Approach

In the following sections, we provide a preliminary examination of the potential consequences of replacing wetlands in urban and suburban areas with wetlands in areas further from urban centers. The basic approach we take is to consider how the location and landscape context of wetlands affect the values they provide to human society. First, we introduce some conceptual tools for understanding wetland functions and values in a landscape context. We then present three examples in which location plays an important role in determining wetland functions, values, or both. Finally, we present analytic tools that may help wetland managers and others assess how location and landscape context will affect wetland functions and values on a case specific basis.

CONCEPTUAL TOOLS

Wetlands are natural systems that exist independent of their significance to humans. Unlike an automobile that has a specific purpose for which it was designed, a wetland has no specific purpose, yet it generates a variety of benefits for humans. Conventional treatment of wetland benefits recognizes this fact and distinguishes between wetland functions and wetland values. Objectively measurable properties of a wetland (e.g., size of a breeding duck population, denitrification rates) are considered functions. Subjective experience of the wetland or the flow of products and services it produces (e.g., good bird watching, improved downstream water quality) are considered values. To a first approximation, functions are the domain of natural scientists and values are the domain of social scientists, philosophers, and politicians. Functions are a property of the wetland alone; values are a property of the interaction of the wetland and its functions with social, political, economic, and ethical systems.

Values of wetlands and other natural systems come in many forms. While the market values produced by wetlands (timber, fish, hunting rights, etc.) are often the easiest to understand and measure, wetland values are much broader, and include nonconsumptive use values (e.g., education), nonuse values (e.g., flood protection), option and bequest values (value of potential future wetland benefits, to oneself or later generations), and existence values (values of knowing something exists). Moreover, some wetland values accrue far from the wetland that provides them because of movement of water and migratory fish, mammals, and birds. These off-site values are no less important than on-site values, but they are much harder to understand and measure, and much harder to manage.

The practical difficulties of tracing chains of causation from wetland functions to discrete wetland values are formidable. Figure 1 suggests the complexity of the task for a single wetland function, sediment trapping. Many wetlands trap and retain sediments because water flow velocities in wetlands are typically too low for sediments to remain suspended in the water column. Thus, owing to purely physical processes, many sediments that enter wetlands in association with flooding events or through overland flow settle out in the wetland, reducing the sediment loads of adjacent water bodies. Reduced sediment loads alter a series of ecological and physical properties of downstream environments, each of which in turn has linked ecological, physical, and economic impacts. Many distinct values are ultimately affected by wetland sediment trapping functions. Moreover, several causative pathways may lead from this function to changes in a single wetland value (e.g., support of biodiversity). This complexity is further compounded by the geographic distance that often exists between the site of wetland functions (the wetland) and the sites at which values accrue (Bohlen 1992). Thus, wetland functions and wetland values are related, but not in the simple and direct way that is sometimes assumed in a wetland management context, in which one must evaluate the extent to which one wetland is equivalent to another in environmental and economic terms.

EXAMPLES

Function Depends on Location: Biodiversity

Metapopulations are collections of interdependent, semiautonomous populations of an animal or plant species of interest (Gilpin and Hanski 1991). Although each component population may persist for many years, occasionally, site-specific processes may lead to the extirpation of one or more of the component populations. Recolonization from adjacent, extant populations can reestablish the population. A component population that goes extinct under one set of conditions (e.g., a dry year) may be highly successful under other conditions (a wet year), which may nevertheless threaten other populations with extinction. Thus,

Figure 1. Tracing economic significance of wetland sediment trapping function.

populations may be dependent on one another for recolonization in the event of a local extinction, as well as for infrequent outcrossing to maintain genetic diversity. The metapopulation as a whole is thus more resilient than the populations of which it is composed.

Metapopulations in fluvial (stream and river) and flood plain ecosystems are likely to have unique features because of stream geometry. Unlike habitat islands in an upland matrix, fluvial habitat patches are linked by a branched and directed stream network. Small, low-order streams join to become larger-order streams, which eventually make large river systems. Water flow moves organisms and propagules preferentially downstream, from low-order streams to higher-order streams, which often provide qualitatively different habitat conditions (Vannote 1972). This branched topology has profound implications for dispersal patterns within fluvial ecosystems. Locations, especially in small, low-order streams, that appear close together on a topographic map may be separated by large stream distances, and thus may be effectively isolated from one another for dispersal of aquatic species. Moreover, dispersal probabilities for many species along stream reaches may differ depending on whether dispersal is occurring upstream or down. These properties suggest that fluvial metapopulations may be strongly dependent on key populations located at or near branch points in river and stream systems that can link otherwise separated upstream populations.

Humans have long relied on surface waters for irrigation, drinking water, transportation, and waste removal services. Thus, many urban areas worldwide are located at the confluence of rivers and streams, at the mouths of rivers, and on estuaries. These locations, selected by humans as locations for large settlements, may be (if this description of metapopulation dynamics in fluvial systems is correct) likely to harbor key

Figure 2. Metapopulations in fluvial ecosystems.

metapopulation links for a variety of aquatic, flood plain, and river bank species (see figure 2). Thus, human patterns of land use may sever dynamically important links among the component populations of fluvial metapopulations. Stream reaches in and immediately downstream from sites of human habitation are the most likely stream reaches to show signs of degradation under anthropogenic impacts. Yet protection of biodiversity in the larger stream network may require management of those same stream reaches to provide at least some base level of habitat for fluvial plant and animal species.

Thus, wetland mitigation practice that overlooks urban and suburban mitigation efforts in favor of rural projects may jeopardize habitat functions in urban and suburban areas that play an important ecological role in the larger landscape pattern, and thus may be especially valuable.

Value Depends on Location: Stormwater Management

The value of certain wetland functions depends completely or nearly completely on where those functions occur within the context of human-altered landscapes. Where wetland functions are significant because they ameliorate negative consequences of human activity, or because they support productive human activities, they may require proximity of human populations or the presence nearby of specific human uses, impacts, and needs.

Stormwater engineers have been experimenting with the use of artificial wetlands for stormwater management (e.g., Schueler 1992). However, in addition to control of stormwater quantity, stormwater wetlands provide improved water quality through trapping and biological processing of sediments, nutrients, and toxic organic compounds. These values of stormwater management wetlands depend upon their location within an urban or suburban context; most wetlands embedded in more natural landscapes cannot provide similar functions. Without excess stormwater generated by impervious surfaces like parking lots, roads, and rooftops, there can be no benefits from stormwater attenuation. Without elevated concentrations of pollutants in stormwater, a wetland's ability to trap or eliminate pollutants has little value.

While natural wetlands are sometimes geomorphically unstable in the flashy stream systems of urban landscapes, where they do persist (including in many suburban landscapes), natural wetlands can provide similar stormwater treatment and water quality benefits to those provided by engineered wetlands. Thus, off-site wetland mitigation, if improperly handled, runs the risk of trading a wetland that provides valuable services ameliorating the consequences of suburbanization for one that, simply because of its location, cannot.

Value Depends on Proximity to Humans: Forest-Interior Birds

Functional Comparisons

From a purely functional perspective, the quality of habitat for forest-interior birds, and especially neotropical migrants, provided by a forested wetland will be greatest if that forested wetland is located far from urban areas in a largely rural, nonagricultural landscape. On an acre-by-acre basis, therefore, a forested wetland in an urban setting is likely to support fewer birds and harbor fewer birds species than a similar wetland in a less altered landscape; forested wetlands in suburban and agricultural landscapes are likely to be intermediate in habitat quality.

The differences in habitat quality are a consequence of three properties of the changing landscapes across the urban-rural gradient. First, contiguous forest patches (of which a forested wetland would be part) are likely to be small in an urban landscape, intermediate in agricultural and suburban landscapes, and largest in nonagricultural rural areas. Second, the lands surrounding forest patches in an urban landscape provide few resources for forest-interior birds. In a suburban or rural landscape, in contrast, surrounding land includes a mix of land uses, including forest patches, lightly forested suburban areas, and agricultural lands, some of which may provide resources valuable to forest-interior species. Finally, extant forested areas in urban and suburban landscapes tend to be fragmented by roads, power lines, and other linear structures, while forest patches in agricultural and nonagricultural rural areas tend to be less fragmented. Each of these changes tends to make urban wetland forest less likely to support a robust population of forest-interior birds than wetland forests in other landscapes.

Value Comparison

The value of a forested wetland as habitat for forest-interior birds, unlike purely biophysical measures of wetland performance, is sensitive not only to habitat quality but also to the way humans interact with and perceive that quality. Undoubtedly, individuals vary widely in whether and how they appreciate (value) forest-interior birds. Some may be content merely to know that rare warblers continue to exist. Others may value the experience of hearing the songs of warblers and other birds, while some serious birders may enjoy the opportunity to add an unusual species to their life list. To still others, the wetland and its birds may provide an outdoor classroom or laboratory in which to learn and through which to enrich the enjoyment of life for themselves and others.

Many of the diverse ways that people appreciate wetland forest birds depend on physical proximity of the person to the bird. One cannot enjoy the sound of bird song if one is too far away to hear it. Moreover, the benefits to one person hearing a bird singing are little affected by the fact that others have seen or heard the bird that same day (bird song is a nonconsumptive good). Thus, the total, society-wide benefits of wetland forest bird habitat generally increase as more people are able to share in them—at least until the presence of many humans deteriorates environmental systems that support the birds, or destroys the broader aesthetic experiences of which hearing bird song is a part.

In addition, as the abundance of suitable habitat for forest-interior birds in the nearby landscape increases, the value of adding another acre of suitable habitat (the marginal value of habitat) is likely to decline. In general, habitat for warblers and other forest- interior birds is relatively scarce in most urban landscapes and relatively abundant in rural areas. Thus, construction of a forested wetland in a rural landscape whose forested wetlands are already abundant is likely to provide fewer values than construction of a forested wetland that provides similar habitat quality in an urban or suburban landscape.

Thus, there is an important trade-off between habitat quality, which often increases from urban to rural landscapes, and the societal value of habitat, which may decrease along the same landscape gradient. Whether a full assessment of this trade-off would favor preservation or construction of wetlands close to or far from urban areas will differ from case to case, but is clearly important in evaluating off-site mitigation. Critical trade-offs can be evaluated only by carefully considering specific wetland management goals, the ecology of wetland systems, and the way in which humans perceive and value wetlands.

ANALYTIC TOOLS

The evaluation of off-site wetland mitigation alternatives is a complex process. As the preceding examples show, the evaluation requires regulators to weigh a wide variety of ecological, social, and economic factors in order to assess whether or not a particular mitigation proposal should be accepted. We offer here two simple analytic tools that may be useful to wetland managers and others when considering on-site and off-site mitigation alternatives.

Functions and Values across a Landscape Gradient

The functions and values provided by a created or restored wetland are both likely to change in predictable ways as a proposed mitigation site changes from an urban setting to a suburban or rural landscape. Values, however, do not necessarily change by the same magnitude or even in the same direction as functions. Moreover, each wetland function and each wetland value may exhibit different patterns of change across the landscape gradient. A simple graphical framework for understanding these patterns on a qualitative basis is presented in figure 3.

Figure 3. Wetland functions and values across a landscape gradient.

Functions

As one moves from urban centers through suburban areas to rural landscapes, the functions of an acre of wetland change. In general, the overall quality of a wetland constructed for mitigation purposes is likely to increase. Specific wetland functions, however, may increase, decrease, or change in some more complex way. Some wetland functions (e.g., flood storage capacity) are determined primarily by properties of the wetland itself and show little change with landscape context. Other functions are controlled by dynamic relationships between the wetland and its surroundings and show substantial changes in response to changing landscape context.

Habitat functions and sediment trapping functions demonstrate contrasting ways in which wetland functions may vary according to the condition of the surrounding landscape. Most habitat functions of a created or restored wetland can be expected to increase as one moves farther from urban centers, and the proximity of the wetland to, and average quality of, adjacent habitat patches improves. Thus, habitat functions typically are inversely related to the level of urbanization of the surrounding landscape.

The degree to which a wetland traps sediment, on the other hand, depends on both wetland hydrology and the influx of sediments from the surrounding landscape. Without sediment influx induced by nearby land use practices, the wetland may have the capacity, but not the opportunity, to trap sediment. The clearing of land for road construction and development of suburban subdivisions is a major source of sediments to aquatic environments in the Chesapeake watershed. Conventional agricultural practices, in which soil bare of crops or crop residues may be exposed for extended periods, provides another important source. Thus, the opportunity to trap sediments is likely to be greatest in agricultural and suburban landscapes, intermediate in urban landscapes, and lowest in extraagricultural rural landscapes.

Values

Even in the absence of functional differences, wetlands embedded in different landscape contexts can generate substantially different values and, perhaps more importantly, provide those values to different segments of society. First, the marginal value of a particular wetland function (the value of a small change in the level of the function) may be expected to decline as one moves from landscapes where wetlands and healthy environmental assets are relatively scarce to landscapes where they are relatively abundant. Construction of a forested flood plain wetland for mitigation along a stream that already has a substantial forested flood plain, for example, may be of little value to society; if the stream in question is already healthy, water quality and ecosystem support services provided by the extra wetland area may be of little consequence. Construction of a similar wetland in a suburban area, in contrast, may offer new recreational opportunities and make a significant difference in the health of adjacent stream systems.

The value of certain wetland functions are also affected by the wetland's proximity and accessibility to human populations, and thus by the distribution of populations, roads, and other transportation facilities surrounding the wetland. Values associated with consumptive and nonconsumptive uses of wetlands, such as hunting or bird watching, drop off quickly as the distance from the wetland increases. Nonuse values associated with the continued existence of a rare animal or plant species, on the other hand, are less dependent on access or proximity and within certain limits drop off only slightly with distance. Off-site values and nonuse values such as flood protection, water quality benefits, and general ecosystem support fall somewhere in between, with values depending on proximity to ecological systems linked to the wetland, but not necessarily to the wetland itself.

These kinds of relationships can be depicted as shown in figure 3b, where the overall value of a hypothetical wetland function is shown to depend on the *per capita marginal value* of the function and also on the *size of the population* that receives the resulting value. By considering, at several locations along an urban-rural landscape gradient, the scarcity value of specific wetland functions of management interest and the number and kinds of people who will receive value at various locations, it should be possible to get a clearer idea of how wetland values change across the landscape gradient, and thus make better wetland mitigation decisions.

If one is concerned only with the number of songbirds in the region, it may make sense to favor mitigation sites in rural areas where land costs are low, the surrounding landscape is relatively healthy, and mitigation success is likely. On the other hand, if one is concerned about how many people have the opportunity to hear songbirds or the consequences for society at large of the existence of urban populations that have no regard for songbirds, there may be reason to favor more urban mitigation sites despite the higher costs and more exacting construction requirements.

Figure 4. Geographic scale of wetland benefits and management.

Wetland Values and Functions at Multiple Scales

A variety of ecological phenomena, especially at the ecosystem and landscape levels, can be understood as consequences of dynamic systems operating at multiple, interdependent spatial and temporal scales (O'Neill et al. 1986). Considerable insight into wetland ecology, management, and politics can be gained by consideration of the scales over which wetland functions and values occur and are managed. Understanding the multiple scales of wetland management may be especially important in the context of off-site wetland mitigation and mitigation banking.

Figure 4 presents a framework for analyzing wetland management efforts in terms of the scales of strong functional dependence of natural processes and the scales over which the values of wetlands are perceived. The diagram is based on three observations: (1) some, but not all, wetland functions are dependent on phenomena that occur far from the wetland. (2) certain wetland values accrue primarily within the wetland, to wetland owners and others with direct physical access to the wetland, while other wetland values accrue at least in part to people far from the wetland itself; and (3) the scales of functional dependence (which determines effective scales of management), and the scales over which benefits accrue (which provides incentive for management), need not be the same.

Functional Dependence

Wetland functions (and thus the values that derive from them) depend on the physical and biological environment of the wetland. However, the scale over which that dependence is significant for management purposes differs among wetland functions. Thus, production of timber in forested wetlands depends loosely, if at all, on conditions outside of the wetland itself, and timber production can be managed on a wetland-by-wetland or even acre-by-acre basis with little need to consider conditions elsewhere. Waterfowl populations in the Chesapeake region, in contrast, cannot be effectively managed without consideration of conditions hundreds and even thousands of miles away along migration routes, and in breeding areas.

For any wetland function, one can identify a range of spatial scales over which actions may be necessary for effective management. For most wetland functions, the smallest scale of management is on the order of a few meters or tens of meters, but the largest scale that needs to be considered varies widely. Wetland functions near the top of figure 4 will be difficult to manage without considering larger-scale (regional, continental) phenomena. Wetland functions near the bottom of the figure can be managed primarily through local action.

Scales Over Which Values Accrue

Values derived from specific wetland functions also accrue at certain relatively well defined spatial scales. The value of a tidal wetland for producing salt marsh hay, for example, accrues directly to the landowner or farmer. The benefits of waterfowl hunting accrue to those with physical access to the wetland. In contrast, benefits of flood attenuation by flood plain wetlands typically do not accrue to the landowner, but to people living some distance downstream. And benefits of the water quality functions of wetlands are often realized in lakes, impoundments, and estuaries like Chesapeake Bay that may be hundreds of miles away. The benefits of certain wetland functions (e.g., carbon sequestration, biodiversity) may even accrue over global scales. Figure 4 displays some of these differences in the spatial scale over which wetland values accrue. Wetland values shown toward the right-hand side of the figure are those that may be expected to accrue a substantial distance from the wetland itself; wetland values toward the left-hand side accrue primarily in or near the wetland itself.

Implications

The scales over which the benefits of specific wetland functions accrue, and the scales over which those same wetland functions can be managed, do not necessarily match. Where the two scales do not match, wetland managers with the strongest political or financial incentives to protect wetland functions may be unable to do so. At one extreme, one may consider a globally significant wetland function—carbon metabolism. Carbon sequestration and production of methane are wetland functions that depend on anaerobic conditions within wetland soils. These conditions are hardly influenced by properties of the landscape outside of the wetland, except insofar as those conditions alter properties of the wetland, yet the effects of wetland carbon metabolism on atmospheric chemistry have global consequences. Landowners, who are best placed to manage wetlands as carbon sinks have little incentive to do so, while the incentive to manage for carbon uptake and storage is felt most strongly at national and international levels, where appropriate management tools short of coercive measures are few.

Scale-explicit analysis may also highlight some of the most significant and most often neglected consequences of off-site wetland mitigation and mitigation banking. A decision to accept off-site wetland mitigation is a decision to accept a trade of wetland functions and values between locations. Successful off-site wetland mitigation may have little effect on values that accrue primarily on the scale of the wetland. Production of timber, for example, will simply have moved from one location to another, but need not be diminished overall. Similarly, off-site mitigation is unlikely to have much effect on wetland values that accrue over spatial scales larger than the distance between the original and mitigation wetlands. If microbial ecology at the two sites is similar, the global carbon balance will not be altered appreciably if a wetland is lost near Annapolis and replaced 20 miles away in southern Anne Arundel County, Maryland. Off-site mitigation will, however, affect wetland values that accrue outside of the wetland itself, but on a spatial scale similar to or smaller than the distance between the original and mitigation wetland. Such values are most likely to include benefits to local and regional populations of humans, fish, and wildlife, and benefits that accrue to downstream ecosystems and human communities, including value of wetlands as components of a regional habitat mosaics, energetic and functional linkages between wetlands and adjacent stream and estuarine ecosystems, water quality benefits, protection from flooding and storm damage, and other primarily regional wetland benefits.

CONCLUSION

Wetland mitigation efforts and wetland mitigation policies have been based to a large extent on site-by-site comparisons of wetland functions and values. While such a local approach is sufficient when off-site wetland mitigation is rare, it does not provide the necessary perspective to address the complex issues raised by widespread adoption of off-site mitigation or by the proliferation of mitigation banking programs. Both trends require the development of conceptual frameworks and management tools that explicitly address the spatial structure of wetlands, watersheds, and land-scapes from both ecological and economic perspectives.

Even relatively simple analytic and conceptual tools can help clarify the trade-offs wetland managers should consider when evaluating off-site wetland mitigation alternatives. Consideration of how wetland functions and values are likely to vary in different landscape contexts, and consider-ation of the scales over which wetland functions develop and over which wetland values accrue are crucial for evaluation of wetland policy within a landscape or watershed perspective. Analytic tools developed for this purpose can help wetland managers recognize which wetland functions and values are most at risk when considering off-site mitigation alternatives and in determining of the size and location of trading territories and trading rules to be used by regional mitigation banks.

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Measuring the Price Effects of Shoreline Erosion on Chesapeake Bay Area Properties Using the Hedonic Price Approach

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Abstract: In efforts to preserve human investments in the face of dynamic natural forces, the U.S. Army Corps of Engineers(COE), values the cost of the square footage of shoreline property lost to erosion. This study, funded by the COE explores methodological and practical aspects of using hedonic price indices for waterfront and nonwaterfront properties as an alternative approach.

Two years of market transactions for Chesapeake Bay-side properties in Calvert County, Maryland, are evaluated. Results indicate that the market pays a premium for location within a waterfront community and the premium is reduced when erosion diminishes the size and character of the shoreline. When erosion diminishes the shoreline, all homeowners within adjacent communities are affected. The total reduction of value for more numerous nonwaterfront properties can be greater than the total reductions in value of shoreline properties. The average reduction per property is $3,474 per annual foot of erosion and an additional loss of $6,622 per property accrues if erosion reduces the quality of the beach area in a waterfront community by one rating point on a relative scale from 0 to 5.

Losses specific to waterfront properties are also identified. If a waterfront property suffers severe erosion resulting in loss of a sandy walking shoreline for the property, the value of a waterfront property is reduced by $42,537 on average. If, in response to severe erosion, the waterfront property is protected by a revetment, the value of the waterfront property is reduced, on average, by an additional $36,188.

OVERVIEW

This study is designed to measure the price effect of erosion on property values. Specifically, the hypothesis tested is whether (in Calvert County, Maryland, communities along the Chesapeake Bay) erosion of the shoreline has resulted in diminished property values. In some areas, severely depleted shorelines have resulted in waterfront structures that are dangerously close to the mean high tide level. In a severe storm, these structures are subject to wave damage and flooding. Unbuilt waterfront lots in these communities have been reduced by erosion and may no longer meet minimum size requirements for development. Some community beaches are no longer large enough to support recreation. Even without the devastation from a severe storm, the slower effects of annual erosion could render some of the waterfront properties (built and unbuilt) and beaches worthless.

In some communities along the Bay, erosion has already changed the shoreline. Communities that were developed along a shoreline that once offered sandy beach areas have lost them. To prevent loss of waterfront structures, including houses and roads, stone revetments and/or bulkheads have been constructed. The shoreline has changed from a walk-out sandy beach area to a shoreline protected by a revetment or bulkhead separating existing properties or roadway from the Bay waters. The revetments/bulkheads extend 8 to 15 feet above the mean high tide level.

In communities wherein historic erosion has reduced the beach areas, the hypothesis is that nonwaterfront as well as waterfront properties in the communities have been affected. These communities were developed along shoreline areas with a row of waterfront houses, a cluster of houses behind the waterfront houses, and a community beach. The land area which includes the roads throughout the community and the beach area, is usually owned by the community association or by the corporation (or a successor corporation) that developed the community. As the distance from the waterfront houses to the high tide line has diminished, so also has the size of the community beach. Because purchase of a property within these privately owned shoreline areas includes purchase of rights to and/or partial ownership of a private beach (as well as roads and other community areas), not only have the houses located directly along the shoreline been affected, but the surrounding properties have also been impacted. This research uses the hedonic method to measure the price effects of erosion on properties that are directly affected and indirectly affected by erosion.

How Hedonic Models Work

A house has many attributes such as location, size, the number of rooms, and the materials used in construction. If a buyer wants to purchase three bedrooms, he must buy a house that has three bedrooms. The price of the three bedrooms is intermingled with the prices of other attributes of the house and lot. The buyer pays one price for the house and lot.

The hedonic price index is a statistical method for determining the prices of the individual attributes of properties. Indices generated by the hedonic approach also may be utilized in more extensive applications. Rosen examined how the demand and supply of attributes of a composite product (such as housing) could be estimated (Rosen 1974). He used a multistage regression analysis in which estimating the hedonic price index was the first step.

Regression analysis, the statistical technique used to estimate the hedonic price index, is used in many different applications. The theory of regression analysis is well known and widely discussed. In brief, the goal is to find out how a set of independent variables affects a dependent variable. The basic equation is:

$$y_i = a_0 + a_1*x_{i1} + a_2*x_{i2} + \dots + a_m*x_{im} + e_i$$

where i counts the observations and a_j is the coefficient of x_{ij}, the j^{th} attribute of the i^{th} observation. There is also a random error term, e_i, that accounts for omitted variables. The y_i's and the x_{ij}'s are observed data. The technique allows estimation of the a_j's and the e_i's. The precision of the estimates can be estimated in terms of a confidence interval that assigns a probability that the true value will be within the estimated interval. Additional statistical tests show the percentage of the variation of the dependent variable that is accounted for by the equation and the statistical significance of the individual coefficients.

Hedonic Models Can Estimate the Effect of Erosion on Property Values

Each year, erosion removes sand and other materials from the water frontage of homes situated along the Chesapeake Bay. The erosion rate varies from place to place. Erosion can be reduced, stopped, or sometimes reversed by erosion control projects. The effects of erosion on property values (prices, as reflected in the marketplace) are the focus of this research.

It has long been an open question whether the housing market adjusts for the differing effects of erosion. To date, there is no firm evidence that property values are reduced by erosion. Some observers have speculated that buyers of waterfront community properties are myopic; buyers tend to disregard the effects of erosion. However, this was also the case with respect to floodplains, until W. A. Donneley applied hedonic price analysis to properties in a floodplain in La Crosse, Wisconsin (Donneley 1989). Donneley found that prices of properties located in the floodplain were 12 % below similar properties not in the floodplain. The model Donneley estimated was a simple one that used a small number of commonly available variables and produced statistically significant results. This study builds a similar hedonic model that focuses on the erosion condition to estimate the effect of erosion on the prices of Bay area properties.

Donneley's model produced estimates of the effects of various attributes on property prices with 95 % confidence intervals (meaning that there is a 95 % chance that the true value is in the stated interval), as well as an estimate of the overall ability of the chosen specification of the model to explain the prices of housing in La Crosse.

ISSUES IN HEDONIC MODEL APPLICATIONS

Purpose

The hedonic approach can be limited to defining price indices or broadened to include supply/demand or welfare gains/losses associated with the attributes under consideration. Rosen's model measured demand and supply curves for the attributes of a composite product (Horowitz 1987, Palmquist 1984, Parsons 1986). Rosen first measured the prices of the attributes and then continued by identifying supply and demand curves when the amount of an attribute was altered. In the current study, the hedonic application is used to measure attribute prices without the additional supply/demand analysis. This eliminates from consideration many complex issues discussed in the hedonic literature.

Definition of the Dependent Variable

Three measures of the dependent variable, property value, are (1) selling prices, (2) estimates of property values by tax assessors, and (3) estimates of values by owners. Selling prices are subject to "sample selection bias" because the sample is limited to properties sold during a specific time period and not a random selection of all houses under consideration. The other two value estimates are subject to "measurement error" because of the potential for systematic variation from the true value.

A recent study (Ihlantfeld and Martinez-Vazquez 1986) indicates that the sample selection bias in sale prices of recently sold houses included in their study was trivial and caused much less distortion of the hedonic prices than assessor or owner estimates. The measurement errors in assessor and owner estimates were large and systematically related to important variables.

In the current study effort, the dependent variable is defined by sale prices recorded in recent transactions. Although there may be some selection bias, it is expected to be smaller than the bias that would result if one of the alternative dependent variables were used.

Market Specification

Different markets for housing exist at different times and places (Palmquist 1984, Parsons 1986). The prices of housing attributes may vary between markets. In Rosen's model, these variations in prices are used in the process of estimating demand and supply curves for housing. Because the prices of attributes may vary between markets, the definition of markets affects the ability to measure the price of attributes. If the markets are defined too broadly, the price of attributes within the market may also vary significantly. Thus two identical houses on similar lots but in different locations could exhibit different attribute prices. Moreover, the same property is likely to sell for a different price from year to year. Therefore, each year and locational pairing may constitute a unique or semi-unique market. In this effort, market structure is studied by measuring the effect of different locations and years on attribute prices using "dummy variables."

Multicolinearity

The ordinary least squares (OLS) model, the starting point in the development of regression analysis, assumes that the various independent variables are not correlated with each other. In some applications, especially the analysis of housing prices, some independent variables are highly correlated with each other. For example, floor space may be correlated directly with the number of bedrooms and with the number of rooms. Where correlation occurs, it is very difficult to distinguish the contribution of an individual attribute from the set of correlated attributes. However, the estimate of the price of the house (the dependent variable) is not affected as long as all pertinent variables are included, even though the variables may be correlated. Furthermore, the correlation of some variables does not affect the measurement accuracy of uncorrelated variables. Thus, measurement of the price attributes of erosion is not affected by a correlation between the number of bedrooms and the square footage of the structure. In the current study, careful attention is paid to correlations between independent variables related to the erosion condition and other independent variables. Correlation between variables other than those related to erosion is not a focus of the analysis.

Functional Form

When estimating hedonic price indexes, researchers must choose between a number of different functional forms for specifying the equation being estimated. Often researchers choose functional forms after trying several and testing for the form that maximizes the explanatory power. For example Palmquist (Palmquist 1984) tested seven applications with linear, semi-logarithmic, log-linear, and inverse semi-logarithmic forms based on maximizing the likelihood function in Box and Cox (1964). In six of seven applications, the linear form best fit the criteria; the semilogarithmic form fit best in the remaining application. Other researchers have used other means of selection, either selecting based on convenience or trying several approaches and choosing the one that seems to give the best results.

Cropper et al. note that economic theory places few restrictions on the form of the hedonic price function, but stipulates that the best criterion is the accuracy of the estimates of the marginal willingness to pay for the attributes (Cropper, Deck, and McConnell 1987). Cropper et al. tested a number of forms in a simulated housing market based on Maryland housing and demographic data and assumed utility functions. From the assumed utility functions, they created a market with known marginal evaluations. They then estimated the prices of housing attributes using a number of forms and strategies and identified those forms that gave the best results both in ideal and less than ideal circumstances. The conclusion was that "a linear function of Box-Cox transformed variables produces, on average, the most accurate estimates of marginal attribute prices of the six functional forms examined . . when all attributes are observed without error . . ." Cropper et al. identified the linear form as the second-best choice. Although the linear from did not perform as well as the Box-Cox procedure in ideal circumstances, they concluded that this form "performs almost as well as the linear Box-Cox function" when some attributes "are not observed or are replaced by proxies."

The linear form is utilized in the current effort. The data used in the current effort are identical to those used by Cropper et al. and were from the same region, so her group's conclusions should be ap-plicable to them. Because this project is intended to develop a straightforward method for developing benefit estimates, Cropper's conclusion that the linear form performs adequately is a welcome one.

THE PROPOSED MODEL FOR THE CHESAPEAKE BAY REGION

Because this study observes the effect of erosion on property prices, the price index is estimated. No further steps in hedonic analysis are taken. The dependent variable is the transactions price of properties in the study area over the years 1988-89. Dummy variables for community and year are used to differentiate between different markets. Multicolinearity was not expected to be a problem because coefficients expected to be correlated are not of primary interest to the study. The linear form is used because it provides good ability to estimate the marginal effect of housing attributes on the transaction price in a relatively simple framework.

Variable Definitions

The data set was developed from more than 1,400 records in the Calvert County Assessment Office, which provide the transaction amount, the legal designation of the property, the lot size, and the square footage of the house if the property includes one. Other characteristics of the property, (e.g, the number of bedrooms, baths, presence of air conditioning), are not available from these records. While inclusion of variables that further describe the house characteristics may help explain the price of the house, it is unlikely that their presence would affect the explanatory capability of the erosion measures. Moreover, inclusion of the additional variables would reduce the number of available records from the 1,400 plus available from the assessment office records to the roughly 200 contained in the multiple listing service (MLS) for the same period. Because a larger sample size generally yields better statistical results, the much larger data set was selected over the smaller set that included more specific delineation of housing characteristics.

The variables used in the current effort are listed in table 1. In the discussion below, they are grouped by category. Variable names are capitalized. Some of the variables regarding the interaction terms for waterfront properties duplicate each other. These duplicate terms are included in the discussion because these terms appeared in the data set when it was used in the analysis.

Dependent Variable

PRICE, the transaction price of real estate measured in dollars, is the dependent variable.

Independent Variables

Land characteristics. These variables describe the property, exclusive of improvements. Erosion,

Table 1. List of Variarable in their order of appearance in the data set.

Variables Affecting All Properties		
v1	PRICE	(Continuous; $)
v2	LAND AREA	(Continuous; sq ft)
v3	HOUSE AREA	(Continuous; sq ft)
v4	AGE OF HOUSE	(Continuous; years)
v5	DISTANCE TO SHORE	(Continuous; ft)
v6	BEACH PUBLIC	(Dummy; 0 or 1)
v7	MARINA	(Dummy; 0 or 1)
v8	BEACH	(Dummy; 0 or 1)
v9	BEACH EROSION RATE	(Integer; ft/yr = -1 through 5)
v10	GROCERY	(Dummy; 0 or 1)
v11	BEACH QUALITY	(Integer; 0 through 5)
v12	WATERFRONT	(Dummy; 0 or 1)
v13	COM 1	(Dummy; 0 or 1)
v14	COM 2	(Dummy; 0 or 1)
v15	COM 3	(Dummy; 0 or 1)
v16	COM 4	(Dummy; 0 or 1)
v17	COM 5	(Dummy; 0 or 1)
v18	COM 7	(Dummy; 0 or 1)
v19	COM 8	(Dummy; 0 or 1)
v20	COM 9	(Dummy; 0 or 1)
v21	COM 10	(Dummy; 0 or 1)
v22	COM 11	(Dummy; 0 or 1)
v23	COM 12	(Dummy; 0 or 1)
v24	YEAR OF SALE	(Dummy; 0 or 1)
v25	HOUSE ON LOT	(Dummy; 0 or 1)
v26	SANDY PLACE TO WALK	(Dummy; 0 or 1)
Variables Affecting Waterfront Properties Only		
v27	CLIFF	(Dummy; 0 or 1)
v28	REVETMENT	(Dummy; 0 or 1)
v29	EROSION RATE	(Integer; ft/yr = -1 through 5)
v30	SANDY PLACE TO WALK * WATERFRONT	
v31	FRONT FOOTAGE	(Continuous; ft)
v32	LOT DEPTH	(Continuous; ft)
v33	DISTANCE HOUSE TO WATER	(Continuous; ft)
Interaction Terms		
v34	BEACH EROSION RATE * BEACH QUALITY	
v35	BEACH EROSION RATE * WATERFRONT	
v36	BEACH EROSION RATE * SANDY PLACE TO WALK	
v37	BEACH QUALITY * WATERFRONT	
v38	BEACH QUALITY * SANDY PLACE TO WALK	
v39	WATERFRONT * SANDY PLACE TO WALK	

location, neighborhood and other characteristics of the lot are included under land characteristics because they are associated with the property whether or not the property includes improvements.

Erosion variables. Two types of erosion variables are utilized. Erosion variables are used to characterize (1) the current shoreline condition and (2) the historic rate of erosion for waterfront properties and associated beaches. Six variables were used to characterize the current shoreline condition. All properties were assigned a measure of the BEACH QUALITY (a relative scale of unit values from 0 for the poorest beach quality to +5 for the best) for the beach area within the community or for a nearby public beach and a dummy variable indicating the presence or absence of a SANDY PLACE TO WALK within the community. Shoreline condition variables specific to waterfront properties were LOT DEPTH (the distance from the back edge of the property to the high tide line), DISTANCE HOUSE TO WATER (the distance from the front of the house to the high tide line), a dummy variable indicating the presence or absence of a sandy place to walk for the individual waterfront property, and a dummy variable indicating the presence of a REVETMENT on the property.

Two variables were used to depict the historic rate of erosion. For all properties within the community, the historic BEACH EROSION RATE was used to represent the community's general rate of erosion. For waterfront properties, the historic EROSION RATE for the property also was included in the record. In the end, EROSION RATE for an individual waterfront property equaled BEACH EROSION RATE for its community. Both erosion rates were entered according to a unit scale from -1 to +5. If the area was increasing in beach area (from natural attrition or via beach replenishment), the value was entered as -1. If the erosion rate was 0 because no erosion was observed historically or because of the presence of a substantive revetment, the value was 0. A unit value of +1 to +5 was given for historic erosion rates of .1 - .9, 1.0 to 1.9, 2.0 to 2.9, 3.0 to 3.9, and 4 feet or more per year, respectively.

The erosion rates used were based on maps published in 1975 by the Office of Coastal Zone Management of the Maryland Department of Natural Resources. These maps were created as part of a study in the early 1970s wherein the Maryland Geological Survey took field measurements of the shoreline and updated a 1947 study "Bulletin 6: Shoreline Erosion in Tidewater Maryland "(Maryland Department of Geology, Mines, and Water Resources, now known as Maryland Geological Survey). The 1947 study compared the existing shoreline to earlier shoreline surveys that were available from as early as the 1850s.

Location. The location of each property was described by a number of variables. Dummy variables, COM 1-12, were specified to indicate the location of a property within a community. The communities in order of number are:

COM 1: North Beach
COM 2: Chesapeake Station
COM 3: Chesapeake Beach
COM 4: Holiday Beach
COM 5: Breezy Point
COM 7: Dares Beach
COM 8: Scientists Cliffs
COM 9: Western Shores
COM 10: Park Chesapeake
COM 11: Drum Point
COM 12: Chesapeake Ranch Estates

There were no transactions records for community 6, so it was dropped from the data set. DISTANCE TO SHORE indicated the distance from the property to the shoreline, in feet. Dummy variables were used to indicate distance to the beach (BEACH = 1 if distance less than 0.5 mile), distance to a marina (MARINA = 1 if distance less than 0.5 mile) and distance to a grocery store (GROCERY = 1 if distance less than 5.0 miles).

Other Characteristics. Seven other characteristics describing the property include LAND AREA (area of lot in square feet), WATERFRONT (a dummy variable, 1 if lot is waterfront, 0 otherwise), FRONT FRONTAGE (for waterfront properties only, the length of shoreline for the lot, 0 for nonwaterfront properties), BEACH PUBLIC (a dummy variable, 1 if property relies on a public beach area, 0 otherwise), CLIFF (a dummy variable for waterfront properties only, 1 if shoreline is a cliff, 0 otherwise), YEAR OF SALE (a dummy variable, 1 if property is sold in 1989, 0 if the property sold in 1988), and HOUSE ON LOT (a dummy variable, 1 if the property includes a house). These complete the list of variables applicable to properties whether or not they are developed.

House characteristics. The next two variables apply only to developed properties. The first is AGE OF HOUSE (years since house was built) and the second is HOUSE AREA (area of house, in square feet).

Interaction terms. Interaction terms are the product of two or more variables. They explain the joint effect of two or more factors. As such, they are useful for indicating certain forms of nonlinear behavior in the data. Six interaction terms were included in the data set for this study, They were (1) BEACH EROSION RATE * BEACH QUALITY, (2) BEACH EROSION RATE * WATERFRONT, (3) BEACH EROSION RATE * SANDY PLACE TO WALK, (4) BEACH QUALITY * WATERFRONT, (5) BEACH QUALITY * SANDY PLACE TO WALK, and (6) WATERFRONT * SANDY PLACE TO WALK.

Interpretation of Specification

Owing to the inclusion of dummy variables and interaction terms, it is necessary to consider how the results of the model will be interpreted. Each dummy can be set at 0 or 1. If all dummies are set to zero, the property so described is in a community wherein the community coefficient was not significantly different from that of community 4, Holiday Beach, and the property was sold in 1988. These were chosen as the “base case” for ease of analysis. The property is not on the waterfront, is located more than 5 miles from a grocery, more than .5 miles from a marina, does not have a house on it, and is not located within a community that has a sandy walking shoreline. The property is in a community that relies on a private beach within the community for recreation. The “zero” case for dummy variables need not exist.

The effect of erosion (at the margin) on this property can be determined by the variables BEACH EROSION RATE and BEACH QUALITY. A single unit change in these variables would increase or decrease the property’s value by the parameter estimate for the variable. Some of the dummy variables can also be used to estimate the effects of erosion. For example, in the case of a waterfront property, dummy variables indicate the presence of a sandy place to walk near the property and a revetment. If erosion causes a waterfront property to lose its sandy place to walk or necessitates construction of a revetment, the property would be decreased in value by the parameter estimate for the respective variable. If the waterfront property includes a house and the house is destroyed by erosion, the value of the parameter estimate for HOUSE ON LOT also would be subtracted from the PRICE.

DATA MANIPULATIONS AND RESULTS

To test the hypothesis that erosion reduces property values in waterfront communities, we established a data base with complete records and all germane forms of the variables, estimated the linear form of the OLS regression, and summarized the model’s results.

The data collected consisted of over 1,400 records, including both developed and undeveloped lots. To prepare this data base for estimation of a model, records were first sorted based on completeness of the record. Incomplete records were deleted. Most deletions were made because of missing information regarding the size of the house. The resulting data set contains 1,330 records.

Of the 1,330 records, 35 were waterfront properties. Houses occupied 33 of these, whereas 2 lots had no houses on them.

The total number of variables in the data set was 33. An OLS multiple regression was run on this data set, using SAS. Variables were then deleted for one of two reasons. In the first set of runs, variables that were exact linear combinations of other variables in the data set were removed from the data set. These data cause the matrix used in the computations to be singular. Such a matrix cannot be inverted and hence the regression analysis cannot be performed. After removing variables that were linear combinations of other variables, the least significant of those remaining in the model was eliminated from the next run. This process was repeated a number of times. The final model selected is shown in table 2.

The F test reported in the printout of each specification run tests the relationship between the dependent variable and the independent variables. The null hypothesis is that there is no relationship at all. The high F value (130.914) and the low probability (0.0001) that the F value would exceed the critical value for rejecting the null hypothesis if the null hypothesis were true indicates that the model fits the data. The adjusted R-square value of 0.5778 indicates that some missing factors would help to explain the price of the properties in these waterfront communities. This would affect the central concern of this study, whether the erosion rate influences property values, only if the omitted variables are correlated with the erosion rates. However, it is likely that the omitted variables have more to do with the attributes of houses and lots.

Table 2. Specification of final model. Dependent variable: V1

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F
Model	14	2.4106557E12	172189693728	130.914	0.0001
Error	1315	1.7295982E12	1315283765.2		
C Total	1329	4.1402539E12			

Root MSE	36266.84113	R-square	0.5822
Dep Mean	48876.54812	Adj R-sq	0.5778
C.V.	74.20091		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	25387	6745.3316286	3.764	0.0002
V3	1	8.053099	1.83510418	4.388	0.0001
V6	1	37619	7658.8208142	4.912	0.0001
V9	1	-3473.510710	1427.4937975	-2.433	0.0151
V10	1	-42166	8816.5023312	-4.783	0.0001
V11	1	6621.632581	2709.1566927	2.444	0.0146
V12	1	62815	22682.954087	2.769	0.0057
V13	1	-17762	6346.3231602	-2.799	0.0052
V14	1	97156	12331.458940	7.879	0.0001
V22	1	43755	10636.818532	4.114	0.0001
V24	1	4234.749259	2126.7856061	1.991	0.0467
V25	1	47774	3141.1518195	15.209	0.0001
V27	1	-73314	28756.956768	-2.549	0.0109
V28	1	-36188	20053.902747	-1.805	0.0714
V30	1	42537	18480.456407	2.302	0.0215

Variable List

Variables Affecting all Properties

V1	TRANSACTION PRICE
V3	HOUSE AREA (SQ FT)
V6	BEACH PUBLIC=1
V9	BEACH EROSION RATE
V10	GROC=1 LT 5 MI
V11	BEACH QUALITY 5=BEST
V12	WATERFRONT=1
V13	COM 1 NORTH BEACH
V14	COM 2 CHESAPEAKE STATION
V22	COM 11 DRUM POINT
V24	YEAR OF SALE 1989=1
V25	HOUSE ON LOT YES=1

Variables Affecting Waterfront Properties Only

V27	CLIFF=1
V28	REVETMENT=1
V30	SANDY PLACE TO WALK=1

In early runs of the model, the coefficients of two variables, one a dummy for the property being within 0.5 mile of a marina and the other being the waterfront footage of waterfront properties, had negative signs when positive signs were expected. MARINA was eliminated from the model on the grounds that it was an artificial construct in the first place. Its definition is purely ad hoc. It was suspected that the unexpected sign of the coefficient was attributable to its being correlated with an omitted and as yet unidentified variable. It also had an effect on BEACH EROSION RATE. In the case of FRONT FOOTAGE, the cause of the perverse sign is that all of the properties with wide frontages on the water are in the southern communities, much farther from the Baltimore-Washington metropolitan area than the communities with narrow frontages. Front footages are positively correlated with community numbers 1 - 12 which increase from north to south. Thus, the front footage variable was eliminated because it was not measuring the desired attribute of the properties.

Two variables displayed positive signs when negative signs were expected. These were the dummy variables CLIFFS and REVETMENTS. These variables showed signs of being correlated with MARINA, FRONT FOOTAGE, WATERFRONT, the interaction terms, and DISTANCE HOUSE TO WATER. Several specifications of this set of variables were considered before deciding on the final specification.

Each of the variables correlated with CLIFFS and REVETMENTS, except for WATERFRONT, was removed from the final model. MARINA and FRONT FOOTAGE were eliminated as discussed above. The interaction terms were correlated with other erosion variables and were removed. DISTANCE HOUSE TO WATER was removed in the last step because it was statistically insignificant.

RESULTS AND INTERPRETATION

The selected model includes the variables in table 2. All variables included in this model are significant at the alpha = 0.10 significance level and all except the dummy for revetment are significant at the alpha = 0.05 significance level. Although not as significant as the other variables, the revetment variable is a key element in the model. Its exclusion would greatly alter the coefficients of the other variables.

The model confirms the hypothesis of this study by showing that the beach erosion rate for the community is significant in determining the transaction price of all houses in the community. The expected value for the effect of 1 foot of erosion on the transaction price of a property is $3,474. The 95 % confidence interval for the erosion variable ranges from $676 to $6,271. The mean selling price of the properties in this study was $48,876, so the shore erosion effect ranges from 1% to 13% of the mean value. Such a wide range indicates a large variance in the shore erosion effect across properties. This is not surprising given the varied nature of the properties.

The implicit effect of the erosion rate on the price of individual waterfront properties is not significantly different from the effect of the erosion rate on other properties in the community. That is, the variance of that term is large relative to its mean value, so no particular trend was noticeable and the term was dropped from the model. In considering the amount of variance, note that of the 35 waterfront properties, 25 had revetments and of the remaining 10, 2 were on cliffs. Those with revetments could be considered to not have an individual stake in the erosion rate elsewhere in the community it is not know whether a statistically significant difference in the effect of erosion on waterfront properties would have occurred if there were a larger number of waterfront properties with no revetment and not situated on a cliff in the sample; further research using longitudinal data or cross-sectional data on more uniform properties would help to resolve this question.

Accepting the previous result means that if the beach bordering a waterfront community has erosion, it affects the prices of all properties in the community equally. For example, using the erosion coefficient estimated in the model, $3,474 per foot of erosion per property per year, if there are 50 properties in the community, and the erosion rate is 2 feet per year, then the total reduction in the value of the community is 50 * 2 * $3,474 = $347,400. The price of waterfront properties is affected along with all the others, but there is no additional effect of the erosion rate on waterfront properties.

Beach quality also affects all properties in the community. If erosion continues to the point that beach quality is reduced by one point, then an additional $6,622 * 50 = $331,100 of housing value would be lost to the community.

Other variables relevant to erosion control policy decisions are the dummies for the presence of a sandy walking area and for revetments on waterfront properties. The presence of a sandy walking area on a waterfront property adds $42,537 to the property's expected selling price. The 95 % confidence interval for this variable is from $6,315 to $78,759. Revetments on the waterfront property decrease the property's expected selling price by $36,188. The 95 %confidence interval for this variable is from negative $75,494 to positive $3,118. Because the interval contains zero, this variable is not significant at the alpha = 0.05 %significance level. However, it is significant at the alpha = 0.10 % significance level. Its 90% confidence interval is from negative $69,076 to negative $3,300. According to this model, these two variables affect only the selling price of the individual waterfront property.

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In the early stages of the project, there were many uncertainties concerning the scope and direction of the study. These were resolved during several meetings involving Mr. Kidd, Mr. Davis, Ms. Lent, Mr. Lawrence, and Dr. Van De Verg. The openness to ideas and desire for quality in methodology expressed at these meetings set the tone for the completion of the study.

We also thank the Office of Coastal Zone Management of the Maryland Department of Natural Resources for providing the erosion rates used in the study and the Calvert County Assessment Office for use of their data on the transaction prices and attributes of properties sold in 1988 and 1989.

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ECONOMIC RAMIFICATIONS OF THE VIRGINIA CHESAPEAKE BAY PRESERVATION ACT

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Abstract: The Commonwealth of Virginia enacted the Virginia Chesapeake Bay Preservation Act) in 1988. The implementing regulations became final on 15 November 1990. The Act attempts a unique division of authority between the state and localities in developing a conservation policy relating to Chesapeake Bay, a regional and state resource.

The regulations allow, in one provision, farmers a choice in management techniques employed to reach conservation performance standards. However, other provisions of the regulations implicitly mandate the management techniques to be employed. The act fails to consider the economic ramifications to farmers of mandating the choice of management techniques.

Given the emphasis of the Clinton administration on local initiatives for water pollution control, other jurisdictions, as well as federal lawmakers, will be examining the Virginia Chesapeake Bay Preservation Act and its regulations for guidance on further initiatives. This paper examines the effectiveness of the regulatory framework and methods employed by the act and regulations.

A linear programming model is employed to examine the effects of the regulatory mandates. The model determines the most cost-effective means of pollution control based on farm profits under several regulatory scenarios. The results suggest alternative procedures that allow farmers the choice of management techniques employed to reach conservation performance standards.

INTRODUCTION AND DISCUSSSION

The Commonwealth of Virginia enacted the Virginia Chesapeake Bay Preservation Act (the Act) in 1988. The regulations implementing the Act and specifying its requirements became final on 15 November 1990.

The regulations mandate certain management practices for landowners to achieve stated reductions in nonpoint-source pollution. Local governments must adopt ordinances to carry out the mandates of the regulations.

Agricultural production constitutes a major contributor to nonpoint-source pollution ofChesapeake Bay by sediment, nutrients, and pesticides (Norris et al.). "Perhaps. . .the most startling and enlightening finding [of an U.S. Environmental Protection Agency study of the Bay] was that a substantial amount of the high levels of nitrogen and phosphorus present in the Bay came from agricultural activities" (Barker 1990 p. 745). Consequently, the regulations focus a significant portion of their provisions toward the goal of reducing agricultural runoff into the Bay and its tributaries. The regulations establish the goal of achieving a 40% reduction in nonpoint-source pollution from agricultural and silvicultural uses (VR 173-02-01, section 4.1). The regulations employ performance standards to minimize erosion and sedimentation potential, reduce land application of nutrients and toxics, maximize rainwater infiltration, and ensure the long-term performance of the measures employed (VR 173-02-01, section 4.1).

However, the Act and the regulations fail to consider the economic ramifications of the management method mandates. This paper examines the agricultural buffer area requirements of the regulations. The analysis employs a linear programming model, using LINDO software, to determine the economic consequences of the provisions.

The Regulatory Requirements

Resource protection areas constitute the primary focus of regulatory protection under the act (VR 173-02-01, Section 3.2.). Resource protection areas consist of "sensitive lands at or near the shoreline that have an intrinsic water quality value due to the ecological and biological processes they perform or are sensitive to impacts which may cause significant degradation to the quality of state waters" within the regulated area (VR 173-02-01, section 3.2). These areas include tidal wetlands; nontidal wetlands connected by surface flow and contiguous to tidal wetlands or tributary streams; tidal shores; and " [s]uch other lands ... necessary to protect the quality of state waters" (VR 173-02-01, section 3.2).

The resource protection area also includes a buffer area of not less than 100 feet in width and adjacent to and landward of the resource protection area components. Local governments may reduce this buffer area, but only based upon "reliable site-specific information" based on actual field evaluations, review by the Chesapeake Bay Local Assistance Board (an entity established under the act to carry out the purposes of the Act and assist local governments in their duties), or a plan of development procedure designated by the regulations and the *Virginia Code* (VR 173-02-01, section 3.2.5). The buffer area component constitutes the centerpiece of the regulatory pollution control methods. The regulations deem the 100-foot buffer to achieve a 75% reduction of sediments and a 40% reduction of nutrients (VR 173-02-01, section 4.3.B.).

Resource protection areas encompass nearly 221,400 acres within the commonwealth (Evans, page 39). This area includes 1,128 miles of shoreline along Chesapeake Bay and its major tributaries; 20,717 acres of tidal wetlands; and 13,667 acres of buffer area (Evans1990 p 39).

The regulations designate general performance criteria for activities within resource protection areas. Within resource protection areas, further requirements apply to agricultural lands. In general, a100 foot buffer area of vegetation that is effective in retarding runoff, preventing erosion, and filtering nonpoint-source pollution must be established and maintained (VR 173-02-01, section 4.3.B). The buffer area must be managed to prevent concentrated flows of surface water from breaching the area and noxious weeds from invading the buffer area (VR 173-02-01, section 4.3.B.4). The regulations provide for reduction or elimination of the buffer area on agricultural lands under any of the following three conditions:

1. To a minimum width of 50 feet when the adjacent land is enrolled in a federal, state, or locally funded agricultural best management practices (BMP) program, and the program is being implemented, provided that the combination of the reduced buffer area and the BMPs achieves the water quality protection, pollutant removal, and water resource conservation at least the equivalent of the 100 foot buffer area; or,
2. To a minimum width of 25 feet when a soil and water quality conservation plan, as approved by the local Soil and Water Conservation District, has been implemented on the adjacent land, provided that the portion of the plan being implemented for the Chesapeake Bay Preservation Area achieves the water quality protection at least the equivalent of that provided by the100 -foot buffer area in the opinion of the local Soil vs Water Conservation District Board. Such a plan shall be based upon the *Field Office Technical Guide* of the U.S. Department of Agriculture's Soil Conservation Service and accomplish water quality protection consistent with the act and the regulations.
3. The buffer area is not required for agricultural drainage ditches if the adjacent agricultural land has in place BMPs in accordance with a conservation plan approved by the local Soil and Water Conservation District Board.

However, section 4.2.9. of the regulations requires that land within the regulated area upon which agricultural activities are conducted, including but not limited to crop production, pasture, and dairy and feedlot operations, develop and implement a soil and water quality conservation plan. Owners must base the plan upon the *Field Office Technical Guide* of the U.S. Department of Agriculture's Soil Conservation Service and accomplish water quality protection consistent with the act and the regulations (VR 173-02-01, section 4.2.9).

The plan must be filed by 1 January 1995 (VR 173-02-01, section 4.2.9). The particular conditions of each farm, including soil types, slope, drainage patterns, crop cover, and animal populations determine the contents of the plan (Chesapeake

Bay Foundation 1990). Components of a plan may include grassed drainage waterways, rotating crop covers, crop rotation, contour areas, water diversion structures, nutrient management and pesticide management (Chesapeake Bay Foundation 1990).

The “choice” given by section 4.3.B.4. narrows to one: a 25 -foot buffer and an approved soil and water quality conservation plan. Because the regulations require each option to achieve the same performance standards, the only difference between the options should be the cost of compliance by farmers and the government’s cost of enforcement. In an earlier work (Richardson 1994), data were optimized to determine the most cost-effective method for farmers to achieve compliance with the performance standards contained in the regulations, using Richmond County, Virginia, as an illustration.

Richmond County

Richmond County is located in the coastal plains of Virginia adjacent to the Rappahannock River, and lies above the Columbia aquifer, a large aquifer that flows into the Bay. There are 32,316.8 acres of cropland in Richmond County (U.S. Department. of Commerce 1990). The major crops grown are corn, wheat, soybeans, and barley. The two most commonly used crop rotations are corn double cropped with small grains and soybeans, and corn double cropped with small grains and soybeans and a cover crop of rye or rye mixed with crimson clover in the second winter (Zhu et al. 1992) Small grains consist of wheat and barley. Only winter wheat is used in this study owing to a lack of barley data.

Richmond County affects the Bay through nonpoint-source pollution. Runoff into the Rappahannock River, coupled with the leaching of pollutants into the Columbia aquifer, contribute to the degradation of the Bay. The soil type and the extensive use of chemicals increase the probability of groundwater pollution in Richmond County. Suffolk sandy loam is the primary soil type in Richmond County used for agricultural purposes (Diebel, et al. 1992). Suffolk sandy loam has moderate permeability and slow- to- medium runoff. Agricultural discharges of contaminants such as nitrates and pesticides which find their way to the Bay through runoff and seepage, disturb the organisms residing there and change the environment for aquatic life. Richmond County is chosen for analysis because data are readily available.

Data

Rotation constraints are based on the findings of an unpublished study by Guiranna et al. Six of the original agricultural management systems (AMSs) are explored in this study (See table 1). A full list of the original AMSs can be found in Diebel, appendix B.1. The models fail to include original AMS’s that utilize poultry litter because the sources of litter are in the Shenandoah valley. The distance from Richmond County to the Shenandoah valley makes litter use impractical.

The available field hours aggregated for full and part-time operators in Richmond County are taken from the Diebel study (Diebel, 1990). The total acreage available for cropland is 32,316.8 (U.S. Department. of Commerce 1988). To account for buffer areas of 25 feet, 50-feet, and 100-feet, Diebel calculated the total amount of land that the buffer areas encompass. A 25-foot buffer removes 190 acres within the county from production, a 50 foot buffer entails removing 379 acres and a 100-foot buffer consumes 760 acres. This study converts Diebel’s information from a hectare basis to an acreage basis (table 2).

This study does not utilize historical crop yields in Richmond County in the models. Actual crop yield data based upon various AMSs, but does not reflect different yields resulting from the use of different AMS.s Therefore, a formula approach is necessary (see appendix A).

Table 3 records variable costs per acre (excluding labor) associated with each crop in the six different AMSs. Capital costs, which vary widely among producers, and returns to management are not included in variable costs. Consequently, the model fails to consider fixed costs.

The model separately accounts for labor at $4.50 an hour (Zhu 1992). The nineteen year (1970-88) average adjusted prices of corn, wheat ,and soybeans (in 1988 dollars) are $2.52, $3.03, and $6.13 per bushel, respectively (Zhu 1992, page 148).

The Model

Using LINDO software, a mathematical optimization program, a linear programming model determines the optimal AMS to be implemented to maximize producer’s profits in Richmond County (see appendix B). Constraints include rotation and land constraints (which are dependent on the type of buffer area). The model reflects the regulations’ buffer requirements in the land constraint, reducing the total acreage avail-

Table 1. Summary description of cropping activities used in the model. See Diebel (1990), appendix B.1 for a more detailed description of these production activities.

Production Activity[1]	Crop Rotation[2]	Chemical/Nutrient Application Level
AMS 1	C/SB-DC (2 YR)	medium
AMS 2	C/SB-DC (2 YR)	high
AMS 3	C/SB-DC (2 YR)	low
AMS 4	C/SB-DC (2 YR) split nitrogen application	medium
AMS 8	C/SB-DC-RYE (2 YR) mowed cover crop, no till for corn, soybeans	medium
AMS 15	C/SB-DC-MIX (2 YR) green manure	medium

[1] The production activity numbers shown here were used to be consistent with the Diebel (1990) study.

[2] C = corn
SB = soybean
WH = wheat
DC = double-cropped soybeans
MIX = rye and crimson

Table 2. Summary of the land area in Richmond County, Virginia encompassed by the three possible levels of buffer areas required under Virginia law.

Buffer Area Width	Cropland Area
25 Feet	190 Acres
50 Feet	379 Acres
100 Feet	760 Acres

able to account for tillable land encompassed in the buffer. Monthly labor constraints and yield transfer rows are included. The results of the original model using all available cropland in Richmond County are compared with models A, B, C, D, E, F, and G.

Seven separate models show the effect of the regulations' required buffer areas (no buffer, 25 foot, 50 foot, and 100 foot) and different AMSs on profits. The models indicate the profit-maximizing AMS for each scenario. Models A, B, C, and D consider all six of the AMSs as viable for the no buffer (A), 25-foot buffer (B), 50-foot buffer (C) and 100 -foot buffer (D). More realistically, models E and F consider only the two AMSs that are assumed to meet the requirements for buffer reduction outlined by the regulations and incorporate the 25 foot buffer (E) and the 50 foot buffer (F). Only AMS 8 and AMS 15 implement sufficient numbers of BMP's to be considered acceptable for a soil and water quality conservation plan (to reduce the buffer to 25 feet) or for a BMP program (to reduce the buffer to 50 feet). Model G allows only AMS 15 to be utilized and assumes that this AMS is the only AMS to meet act requirements that allow buffer area reduction to 25 feet. Because required BMPs vary from farm to farm, and the regulations lack clarity on this issue, uncertainty exists as to which BMPs are required in each instance.

Assumptions

Models E, F, and G contain several assumptions relating to which practices qualify for reduction of the buffer area to 50 feet (BMP plan) or to 25 feet (soil and water quality conservation plan). Model E assumes that only AMS 8 and AMS 15 would contain BMPs sufficient to qualify as a soil and water quality conservation plan and reduce the buffer area to 25 feet. This assumption is realistic because only AMS 8 and AMS 15 contain any significant BMPs. AMS 8 includes a mowed cover crop and no-till cultivation for corn and soybeans, while AMS 15 includes a cover crop of clover and rye, which is plowed under (green manure).

Table 3. Variable costs per acre (excluding labor) associated with crops from the six different AMSs. For a breakdown of variable costs by crop and rotation see Zhu 1992 appendix B.3.

Crop	Variable Cost ($ per acre)
Corn1	130.36
Wheat1	100.53
Soybeans1	91.50
Corn2	150.88
Wheat2	116.21
Soybeans2	107.41
Corn3	121.96
Wheat3	88.94
Soybeans3	57.63
Corn4	130.36
Wheat4	101.17
Soybeans4	91.50
Corn8	141.01
Wheat8	106.53
Soybeans8	106.68
Rye8	36.21
Corn15	139.33
Wheat15	100.53
Soybeans15	101.67
Mix15	41.22

Similarly, Model F incorporates the assumption that only AMS 8 and AMS 15 contain sufficient BMP's to qualify as a BMP plan and reduction to a 50-foot buffer.

Model G (25-foot buffer) includes an assumption that only AMS 8 incorporates sufficient BMP's to qualify as a soil and water quality conservation plan, allowing reduction of the buffer area to 25 feet. Owing to the site-specific nature of the plans and the ambiguity of the regulations, this assumption may reflect reality in certain instances. However, this highly restrictive model illustrates a general situation that may occur fairly often. Namely, a scenario may arise where the required soil and water quality conservation plan limits the farmer's management options to one or few choices. The limited choice may severely restrict farm profitability.

Other assumptions concerning the production process are made consistent with the neoclassical theory of the firm. First, producers are assumed to be profit maximizers. Second, the producer is assumed to have perfect information about his production function, input prices, and products. Third, inputs are assumed to be homogenous - equivalent in quality and infinitely divisible. Lastly, technology, tastes, and preferences are assumed constant over the period of study.

Results

The objective function maximizes net profit, subject to the constraints. The maximum county-wide objective function value for model A (no buffer, assuming no regulations) is $2,915,866, using AMS 2 (high fertilizer). Model B (25 foot buffer, all AMSs qualify for buffer area reduction) yields $2,898,723, model C (50-foot buffer, all AMSs qualify for buffer area reduction) shows $2,881,579, and model D (100-foot buffer, all AMSs considered) has a maximum objective function value of $2,847,293 (table 4). Models B, C, and D also choose AMSs 2 as the most profitable rotation and level of chemical application.

Models E (25-foot buffer, only AMS 8 and 15 qualify for buffer reduction) and F (50-foot buffer, only AMS 8 and AMS 15 qualify for buffer reduction) maximize profit using AMS 15 (green manure, medium fertilizer), achieving county-wide profits levels of $2,731,503 and $2,715,349, respectively. Model G (25 -foot buffer, only AMS 8 qualifies for buffer reduction) yields a maximum objective function value of only $1,893,219, allowing use of only AMS 8 (mowed cover crop, no till for corn and soybeans, medium fertilizer). These results are on a county-wide basis.

Richmond County consists of 148 farms (Departement of Agriculture and Consumer Services 1992). Table 4 displays profit levels on a county level and an average farm basis (by dividing county level profits by 148 farms). Without regulation, the average farm enjoys a profit of $19,701 before capital costs and return to management. The 100 -foot buffer area requirement alone reduces profit by an average of $463 (to $19,238). However, limitation of AMS to only AMS 8 or AMS 15, to simulate a BMP plan or soil and water quality conservation plan, reduces profit significantly, to an average of $18,347 per farm assuming a 50 foot buffer (practices qualify as a BMP plan, but not a soil and water quality conservation plan). More dramatically, if AMS 8 constitutes the only management system sufficient to reduce the buffer area to 25 feet (qualifies as a soil and water quality conservation plan), per farm average profit dips to $12,792.

Table 5 converts these potential losses to a per acre, per farm, and percentage basis. Using model A, the model assuming no regulation, as a base,

Table 4. Objective function values in Richmond County.

Model	County Level	Farm Level
A. No Buffer	$2,915,866	$19,701
B. 25 Foot Buffer	$2,898,723	$19,585
C. 50 Foot Buffer	$2,881,579	$19,470
D. 100 Foot Buffer	$2,847,293	$19,238
E. 25 Foot Buffer (8 & 15)	$2,731,503	$18,456
F. 50 Foot Buffer (8 & 15)	$2,715,349	$18,347
G. 25 Foot Buffer (8 only)	$1,893,219	$12,792

Table 5. Lost profits owing to implementation of buffer areas. This table uses the no- buffer model (A) as the base for calculations of loss and percentage reduction in profit.

Model	Loss per Farm	Loss per Acre (average)	Percentage Reduction
A. No Buffer	$0.0	$0	0 %
B. 25 Foot Buffer	$0.53	$116	0.59%
C. 50 Foot Buffer	$1.06	$231	1.17%
D. 100 Foot Buffer	$2.12	$463	2.35%
E. 25 Foot Buffer (8 & 15 only)	$5.70	$1245	6.32%
F. 50 Foot Buffer (8 & 15 only)	$6.20	$1354	6.87%
G. 25 Foot Buffer (8 only)	$31.64	$6909	35.0%

the results indicate that imposition of a 100 -foot buffer requirement imposes a $2.12 per acre or $463 per farm cost, or a 2.35% reduction in profit. Although significant, this loss pales in comparison to losses imposed by BMP plans or soil and water quality conservation plans under the models. For example, a reduction to a 50-foot buffer, accompanied by an assumption that only AMS 8 or AMS 15 qualify for such a reduction (model F) imposes a $6.20 per acre or $1,354 per farm cost, or a 6.87% reduction in profit.

The results from model G suggest even more dire consequences for Tidewater farmers. Assuming that only AMS 8 contains sufficient BMPs to qualify as a soil and water quality conservation plan, the model yields a loss from the nonregulated scenario of $31.64 per acre or $6,909 per average farm, or a 35% reduction in profits.

Because farms vary in size and location, some farms border no sensitive areas within the designated resource protection areas and others contain disproportionately high borders. Consequently, these figures constitute averages only. However, the countywide effects constitute large losses. Some farmers may bear these losses in even greater proportion.

Implications

This study considers relatively few AMSs. However, the AMSs used constitute those most used by Richmond County farmers (Guiranna, et al.1991).

The results suggest the effects of the Act on farmers' profitability, as well as policy alternatives.

The more realistic model (in terms of compliance with the regulations) assumes that only AMS 8 and AMS 15 will qualify as containing BMPs required in the BMP program or soil and water conservation plan and sufficient to reduce the buffer area imposed by the regulations. Therefore, the model results suggest that farming practices will not change until soil and water conservation plans are required in 1995. Rational, profit-maximizing farmers will forgo the BMPs and operate with a 100- foot buffer until that time. This practice maximizes farm profits while complying with the performance standard set by the regulations. Farmers receive higher profits than under the other regulatory scenarios, but Chesapeake Bay still receives the benefits of improved water quality.

In the aggregate countywide analysis, the buffer requirement imposes relatively small costs. However, individual farmers may face a burdensome cost if farms have significant boundaries along a waterway or contains other sensitive lands. This model does not estimate this potentially disparate distributive result.

Although the regulations assume that pollution reduction remains unchanged whether the 100-foot buffer or the reduced buffer areas are used (in that the BMP or soil and water quality conservation plans with reduced buffer areas must achieve at least the same reduced pollution as the 100-foot buffer), the plans impose much greater costs. The act affects farming practices, but only through command-and-control direction, not based on economic considerations.

Given the choice, farmers could maximize their profits, while maintaining the required level of pollution control, by utilizing the 100 foot buffer only. However, the regulations hamper the farmer by forcing him / her to adopt a soil and water quality conservation plan by 1 January 1995.

Further, the actual benefits of the 100-foot buffer remain uncertain. The regulations deem the pollution effects from the 100 -foot buffer identical to the effects with reduced buffers and BMPs and / or soil and water conservation plans. Therefore, farmers should be given the opportunity to choose the most cost effective method of pollution reduction. In this case, the 100-foot buffer constitutes the most cost effective method of pollution reduction. In addition, the government incurs reduced policing and enforcement cost with the 100-foot buffer. Policing and enforcement becomes a simple measurement exercise.

This study also fails to consider the impact of federal, state, or local government subsidies or cost sharing. Cost sharing programs encourage the farmer to adopt certain practices by contributing federal and / or state funds to the cost of implementing the practice. The 100 -foot buffer imposes less social cost than the other plans, without apparent effect on pollution control. The regulations presume that each buffer alternative, in combination with the required plan, if any, achieves the equivalent amount of pollution control as the 100-foot buffer (VR 173-02-01, section 4.3.4.).

CONCLUSION

The Virginia Chesapeake Bay Preservation Act represents an innovative approach to the management of critical natural resources. Virginia's experience over the next several years will guide other state and local governments in their approach to similar problems.

However, the regulations raise other concerns by mandating farmers' management techniques in reducing pollution control. A simple linear programming model indicates that farmer profitability could be enhanced, and social cost reduced, by giving farmers a choice of management techniques. Pollution abatement remains equal under this choice scheme.

Some entity (the landowner, the government, etc.) must bear the cost of compliance, implementation, policing, and enforcement of the act and regulations. The proper allocation of these costs is not directly addressed in this study, but should be considered. This study attempts to determine whether less-costly methods of regulatory control than those imposed by the Virginia Chesapeake Bay Preservation Act exist. The question of who holds property rights to water quality constitutes a related, but different, question.

Because the benefit of the buffer accrues to the general public, policy makers should consider "renting" the buffer area from the farmer through judicious use of local, state, or federal government programs. In addition, real property taxation should be reduced or eliminated on the buffer zone.

Policy makers must consider these factors when considering changes to the Act. The same analysis applies to many other natural resource management issues.

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APPENDIX A

The Model

Maximize Profits = (Price X bushels) - (Variable Cost X acres) - (Cost X labor)

Subject to:
1. Rotation Constraints
2. Land Constraints
3. Labor Constraints and Labor Transfer Row
4. Yield Transfer Rows

APPENDIX B

Nitrogen uptake by the crop may be used as an indication of crop yield (Knisel; Heatwole). The following formula converts total nitrogen biomass to crop yield based on the mass balance approach (Schibles et al.; Norris):

CY = TNB * HINDEX / (NB*DENSITY)[1]

CY	=	crop yield
TNB	=	total nitrogen in biomass (total nitrogen uptake for non-legumes)
NB	=	percentage of nitrogen in biomass (lb / acre)
HINDEX	=	the harvest index, ratio of the weight of grain to the weight of total biomass
DENSITY	=	weight of crop grain per unit volume (lb / bu)

DENSITY for corn, wheat, and soybeans is 56, 60, and 60 respectively (Zhu). The NB is 1.35, 1.52, and 2.75 for corn, wheat and soybeans (Zhu). HINDEX is .55 for corn, .55 for wheat, and .30 for soybeans, respectively (Norris). Table 4 records the TNB, calculated by Zhu using CREAMS to simulate nitrogen uptake, along with the calculated yields for each AMS, using the formula.

This formula predicts yields for non-legumes only. Legumes are nitrogen-fixing and therefore yield predictions may not be based upon these calculations. Therefore, this study assumes a crop yield for soybeans of 23 bu / acre, which is consistent with the figure used by Zhu. Yields for the different AMS are different. The yields vary due to the differing availability of nutrients, particularly nitrogen, under each AMS (Zhu, page 146). Factors such as nitrogen application rate, timing and method of nitrogen application, tillage and method of incorporating crop residues and manures influence nitrogen availability to the crop (Zhu, page 146). To the extent these factors vary among the crops the yield factors, as calculated by CREAMS in Zhu, and the consequent yields, also vary.

It is important to note that this linear equation is not an exact formula for converting nitrogen to yield, but only an approximation.

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A Takings Analysis of the Virginia Chesapeake Bay Preservation Act

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Abstract: The Commonwealth of Virginia enacted the Virginia Chesapeake Bay Preservation Act in 1988. The regulations were promulgated on 15 November 1990. The act attempts to reduce pollution in Chesapeake Bay through land use initiatives and mandates implemented by localities.

The Fifth Amendment of the U.S. Constitution provides that "private property [shall not] be taken for public use without just compensation. This provision applies to state action as well by virtue of the Fourteenth Amendment. Compliance with this mandate provides the most daunting challenge faced by innovative environmental regulations. This paper examines the takings jurisprudence of the U.S. Supreme Court, emphasizing the Court's recent pronouncement in *Lucas v. South Carolina Coastal Council.*

The paper discusses the case law in light of the recent resurgence of the property rights movement. The paper then applies the U.S. Supreme Court takings jurisprudence to the Virginia Chesapeake Bay Preservation Act and determines whether the Act is likely to pass judicial scrutiny under the takings clause. The analysis concludes that, properly applied, the Virginia Chesapeake Bay Preservation Act will withstand judicial scrutiny.

INTRODUCTION AND DISCUSSION

In order to address the rapidly escalating environmental degradation of the Chesapeake Bay, the Virginia legislature enacted the Virginia Chesapeake Bay Preservation Act in 1988. The Act consists mainly of broadly stated directives to a newly created citizen board, the Chesapeake Bay Local Assistance Board. The regulations promulgated by the Board pursuant to the act became final on 15 November 1990.

The regulations implement the act and mandate performance criteria for nonpoint-source pollution within the regulated area. The regulations require private landowners to undertake certain land use management tools to achieve the performance standard goals. The key provisions of the regulations compel landowners to maintain a buffer area of vegetation adjacent to sensitive areas.

Given Virginia's traditional policy of allowing local government exclusive control over land use decisions, the regulations immediately prompted questions among citizens. One question, increasingly heard given today's emphasis on property rights, is whether the regulatory requirements constitute an unconstitutional taking of property without just compensation.

The Fifth Amendment of the U.S. Constitution provides that "private property [shall not] be taken for public use without just compensation." The provision applies to state action as well by virtue of the Fourteenth Amendment.

Specifically applied to regulatory takings, an allegation of a "taking without just compensation" asserts that (1) a government regulation lacks a legitimate police power purpose(local governments possess the power to pass laws to protect the health, safety, and welfare of their citizens; this power is called the police power); (2) the means to achieve a legitimate police power purpose are not sufficiently tailored to the particular purpose; or (3) the regulation so restricts the use of the property so as to deprive the property owner of "all economically viable use."

So called takings challenges, where one alleges his / her property has been taken for public use without just compensation, often provide the strictest test for the validity of environmental regulation. This paper briefly summarizes the provisions of the regulations under the act, provides a succinct and simplified explanation of the U.S. Supreme Court's most recent pronouncement on alleged regulatory taking,s and then applies the case law of regulatory takings to the act and regulations.

The Regulations

Resource protection areas form the focus of the regulatory protection (VR 173-02-01, section 3.2). The regulations define resource protection areas as, ". . . sensitive lands at or near the shoreline that have an intrinsic water quality value due to the ecological and biological processes they perform or are sensitive to impacts which may cause significant degradation to the quality of state waters" (VR 173-02-01, section 1.4). The resource protection area ". .. shall include: (1) Tidal wetlands; (2) Nontidal wetlands connected by surface flow and contiguous to tidal wetlands or tributary streams; (3) Tidal shores; (4) Such other lands [under the definition of resource protection areas] necessary to protect the quality of state waters; (5) A buffer area not less than 100 feet in width located adjacent to and landward of the components listed in subdivisions 1 through 4 above, and along both sides of any tributary stream" (VR 173-02-01, section 3.2.B.).

The 100-foot buffer area provides the central means of achieving the performance criteria required within resource protection areas. The regulations strictly control activity within the buffer area, prohibiting the removal of indigenous vegetation, including trees and shrubs, with just a few, strict exceptions (VR 173-02-01, section 4.3.B.1.).

The 100-foot buffer area may be reduced to a width of 50 feet if best management practices (BMPs) instituted immediately landward of the buffer achieve, in conjunction with the reduced buffer, the water quality protection, pollutant removal, and water conservation at least the equivalent of the 100 foot buffer (VR 173-02-01, Section 4.3.B.). The regulations deem the 100 foot buffer to achieve a 75% reduction of sediments and a 40% reduction of nutrients (VR 173-02-01, Section 4.3.B.).

The regulations provide for reduction or elimination of the buffer area on agricultural lands under any of the three following conditions:

1. To a minimum width of 50 feet when the adjacent land is enrolled in a federal, state, or locally funded agricultural BMP program, and the program is being implemented, provided that the combination of the reduced buffer area and the best management practices achieves the water quality protection, pollutant removal, and water resource conservation at least the equivalent of the 100- foot buffer area.
2. To a minimum width of 25 feet when a soil and water quality conservation plan, as approved by the local Soil and Water Conservation District, has been implemented on the adjacent land, provided that the portion of the plan being implemented for the Chesapeake Bay Preservation Area achieves the water quality protection at least the equivalent of that provided by the 100-foot buffer area in the opinion of the local Soil and Water Conservation District Board. Such a plan shall be based upon the *Field Office Technical Guide* of the U.S. Department of Agriculture Soil Conservation Service and accomplish water quality protection consistent with the act and the regulations.
3. The buffer area is not required for agricultural drainage ditches if the adjacent agricultural land has in place BMPs in accordance with a conservation plan approved by the local Soil and Water Conservation District.

In general, when the application of the buffer would result in the loss of a buildable area on a lot or parcel recorded prior to the effective date of the regulations, modifications to the width of the buffer area may be allowed in accordance with the following criteria: (1) Modifications to the buffer area shall be the minimum necessary to achieve a reasonable buildable area for a principal structure and necessary utilities; (2) where possible, an area equal to the area encroaching the buffer area shall be established elsewhere on the lot or parcel in a way to maximize water quality protection; and, (3) in no case shall the reduced portion of the buffer area be less than 50 feet in width there is an exception for intensely developed areas.

Continued use of preexisting structures <u>may</u> be allowed by the local government if no net increase of nonpoint-source pollutant load results (VR 173-02-01, section 4.5.A.)(emphasis added). In addition, exceptions to the regulatory requirements may be granted, but must be "the minimum necessary to afford relief," and must be accompanied by "reasonable and appropriate conditions" as necessary "so that the purpose and intent of the

Act is preserved" (VR 173-02-01, section 4.6.).

The regulations arguably "take" value of the property by: (1) requiring the adoption of a more costly set of management practices, and (2) the removal of land from production.

Lucas v. South Carolina Coastal Council

The Supreme Court most recently examined the regulatory takings issue in which regulations prohibited land use activities of the owner in the case of *Lucas v. South Carolina Coastal Council*, 112 S.Ct. 2886 (1992). Mr. Lucas purchased two lots in 1986 for $975,000. At that time, South Carolina law permitted building homes on the lots. However, in 1988, before Lucas commenced building, South Carolina enacted the Beachfront Management Act. This act resulted in the prohibition, without exception, of any building on the Lucas lots.

In finding that the regulation affected a taking of Mr. Lucas' property without just compensation, the Court fashioned the following four-part test:

(1) legitimacy test
- (i) Is the purpose of the regulatory action a legitimate state interest?
  - (a) If yes, go to (1) (ii).
  - (b) If no, a taking has occurred, compensation is due.
- (ii) Does the means used to achieve the objective substantially advance the intended state purpose?
  - (a) If yes, then go to (2).
  - (b) If no, a taking has occurred and compensation is due.

(2) Does the alleged taking compel the property owner to suffer a physical invasion of his property (or the equivalent)?
- (a) If yes, then a taking has occurred (assuming that physical invasion is never "inherent in the title"; See (4)).
- (b) If no, go to (3).

(3) Does the alleged taking deny the claimant of all economically beneficial or productive use of the land?
- (a) If yes, go to (4).
- (b) If no, no taking has occurred.

(4) The "nuisance exception": Does the regulation simply make explicit what already inheres in the title itself, in the restrictions that the background principles of the state's law of property and nuisance already impose upon the landowner ? Note the nuisance law, stated in its simplist and most basic form, prohibits a landowner from using his or her property in such a way as to harm another landowner's use of his property.
- (a) If yes, no compensation is due.
- (b) If no, a taking has occurred and compensation is due.

Note: The Court did not explicitly set out this framework for the test. This test is the authors' interpretation of the Court's ruling.

Application to the Virginia Chesapeake Bay Preservation Act In General

In light of the recent Supreme Court case, does the Virginia Chesapeake Bay Preservation Act amount to a regulatory taking? This paper shall argues both no and yes and then proposes alternatives to avoid the issue. The alternatives allow the private landowner to defray the cost of compliance by forcing beneficiaries of restricted land use to share the cost incurred by the landowner.

Legitimacy Test

Courts uniformly hold that protection of the environment constitutes a legitimate state interest, which supports regulation (See, e.g., *Lucas v. South Carolina Coastal Council*, 112 S.Ct. 2886 [199]; *Leroy Land Development v. Tahoe Regional Planning Agency*, 939 F.2d 696 [9th Cir., 1991]; *Gardner v. New Jersey Pinelands Commission*, 593 A.2d 251, 125 N.J. 193 [1991]). Mr. Lucas conceded this point prior to trial, indicating that this point is indisputable and well-established (*Lucas* p 2887).

In addition, promulgation of restrictions and regulations pertaining to land use to affect environmental quality benefits is generally accepted by the courts (See, e.g., *Lucas v. South Carolina Coastal Council*, 112 S.Ct. 2886 (1992); *Leroy Land Development v. Tahoe Regional Planning Agency*, 939 F.2d 696 [9th Cir., 1991]; *Gardner v. New Jersey Pinelands Commission*, 593 A.2d 251, 125 N.J. 193 (1991)). Again, Mr. Lucas conceded that the Beachfront Management Act substantially advanced the purpose of environmental protection (*Lucas*, at Page 2887).

The Nuisance Exception

The invasion of one's interest in the use and enjoyment of land or water resulting from another's pollution of surface waters, groundwaters or watercourses, and lakes *may* constitute a nuisance under general nuisance principles (Restatement of Torts, Second, Section 832). However, application of the tangled web of nuisance law to water pollution has proven problematic in the practical application. Very few cases illustrate the point. In addition, the U.S. States Supreme Court, in the *Lucas* case, exhibited reluctance to apply the principle in that situation: "[i]t seems unlikely that common-law principles would have prevented the erection of any habitable or productive improvements on [Lucas'] land; they rarely support prohibition of the 'essential use' of land" (*Lucas*, 2896). Therefore, it is doubtful that a court would rule that the Virginia Chesapeake Bay Preservation Act prevents a nuisance. This point is not clear, however, and would depend upon a case-by-case analysis.

The Virginia Chesapeake Bay Preservation Act Does Not Enact a Taking

Physical Invasion

In an analogous situation, the U.S. Supreme Court has upheld building setback requirements in the face of constitutional challenge. (*Gorieb v. Fox*, 274 U.S. 603 [1927]). Although not identical, buffer requirements are similar in that certain areas of a parcel are rendered useful only as open space in both instances. Building setback requirements may have substantial relation to the public safety, health, morals, and general welfare, and are valid unless clearly arbitrary or unreasonable (*Gorieb v. Fox*, 274 U.S. 603 [1927]). Therefore, the buffer requirement similarly does not constitute a physical invasion.

Denial of All Economically Beneficial or Productive Use of the Land

This test must be viewed by looking at the value of the entire parcel, not just the buffer area. "Takings jurisprudence does not divide a single parcel into discrete segments and attempt to determine whether rights in a particular segment have been entirely abrogated. In deciding whether a particular governmental action has effected a taking, this Court focuses rather both on the character of the action and on the nature and extent of the interference with rights in the parcel as a whole . . ." *(Penn Central Transportation Co. v. New York City*, 438 U.S. 104, 130-131 [1978]). "At least where an owner possesses a full `bundle' of rights, the destruction of one `strand' of the bundle is not a taking, because the aggregate must be viewed in the entirety" *(Andrus v. Allard*, 444 U.S. 51, 65-66 [979]).

Although the imposition of a buffer area may reduce the value of the parcel, a reduction in value is not enough to constitute a taking (see, e.g., *Glodblatt v. Hempstead*, 369 U.S. 590, 592-593 [1962]; *Euclid v. Ambler Realty Co.*, 272 U.S. 365 [1926]). "Clearly, the quantum of land to be considered is not each individual lot containing wetlands or even the combined area of wetlands. If that were true, the Court's protection of wetlands via a permit system would, ipso facto, constitute a taking in every case where it exercises statutory authority" (*Tabb Lakes, Ltd. v. United States*, 10 F.2d 796, 802 [993]).

To the extent that any portion of property is taken, that portion is always taken in its entirety; the relevant question, however, is whether the property taken is all or only a portion of the parcel in question (*Concrete Pipe & Prods. Inc. v. Construction Laborers Pension*, 113 S.Ct. 2264, 124 L.Ed.2d 539 [1993]).

Therefore, facially, the act is valid and withstands a takings attack. However, if a particular parcel, owing to its shape, amount, and location of required buffer area and other factors, becomes useless owing to the act's provisions, the Act may constitute a taking as to that parcel. The Act does not effect a taking unless and until the aggrieved property owner files for and is denied a variance under the act. This provision for granting of variances in extreme cases (VR 173-02-01, Section 4.3 B.2.). separates the Virginia Chesapeake Bay Preservation act from the Beachfront Management Act at issue in *Lucas.* This provision should shield the act from successful takings challenges if prudently applied by the Chesapeake Bay Local Assistance Board and local government officials.

The Virginia Chesapeake Bay Preservation Act Enacts a Taking

The Act Compels the Property Owner to Suffer a Physical Invasion of His Property

The Courts, when inclined to find a taking of property, have often used an analogy to physical invasion (See, e.g., *Nollan v. California Coastal Commission*, 483 U.S. 825 [1987]). In *Nollan*, for example, the granting of a permit was conditioned upon the granting by the landowner of a public easement across the lot behind the owner's dwelling. The U.S. Supreme Court ruled that the easement constituted a "permanent physical occupation" (*Nollan*, p 832).

The analogy for the building setback requirement is not valid. Building setback areas may be mowed, gardened, farmed, picnicked on, etc. The same may not be said for the buffer area under the regulations. The regulations basically require the buffer area to remain in its natural state. In this way, the buffer area more resembles a physical invasion.

"... [T]he fact that regulations leave the owner of land without economically beneficial or productive options for its use typically, as here, by requiring the land to be left substantially in its natural state carry with them a heightened risk that private property is being pressed into some form of public service under the guise of mitigating serious public harm" (*Lucas*, p 2890).

Denial of All Economically Beneficial or Productive Use of the Land

The rule expressed by the *Penn Central* Court no longer controls. That case stated that the parcel is not divided into discrete segments, but viewed as a whole (*Penn Central*, p 130-131). Subsequent cases have eroded their rule.

Justice Scalia, writing the majority opinion in the *Lucas* case, expressed doubt as to this rule. "... The rule does not make clear the 'property interest' against which the loss of value is to be measured. When, for example, a regulation requires the developer to leave 90% of a rural tract in its natural state, it is unclear whether we would analyze the situation as one in which the owner has been deprived of all economically beneficial use of the burden portion of the tract, or as one in which the owner has suffered a mere diminution in value of the tract as a whole" (*Lucas*, footnote 7, p 2893).

The regulations enacted under the act thereby constitute a taking. The area required to be set aside as a buffer is valueless and is left with no economically beneficial or productive use. Richardson showed that the imposition of BMPs, as well as the requirement of the buffer area, can drastically reduce the profitability of the parcel (Richardson, 1994). Richardson's model examined farm profitability under the Act, but the same results should hold for other landowners.

In fact, in the Richardson study, the 100- foot buffer area reduced profits by only 2.35% (Richardson, 1994). However, a 25-foot buffer, in conjunction with a soil and water quality conservation plan, may reduce profits up to 35% (Richardson, 1994). Such a drastic reduction in profitability merits compensation.

In *Dolan v. City of Tigard*, S.C. Docket No. 318, 93-518, argued March 23, 1994, before the U.S. Supreme Court, the landowner applied for a permit to expand her commercial business. The permit to expand the business on a lot with adequate land was granted subject to the landowner dedicating an interest in her property for flood prevention and the public construction of a pedestrian and bicycle path. The conditional permit subject to conveyance was challenged as a taking of property under the Fifth Amendment's takings clause without just compensation. Both the Oregon Court of Appeals and the Oregon Supreme Court affirmed that the required condition was not a taking.

The dissent argued that a "cause and effect" relationship or "essential nexus" must be demonstrated (*Dolan v. City of Tigard*, 832 P.2d 853 [Ore. App., 1992]). The U.S. Supreme Court now possesses the opportunity to more precisely define the parameters of *Lucas*. But *Dolan* is distinguishable from the Virginia Chesapeake Bay Preservation Act issue. In *Dolan*, the landowner asked for an expansion of a business. This request was met with an unrelated property use requirement. Under the act, the landowner is denied economically beneficial use of land now farmed or used in some other fashion.

CONCLUSION

A return to the words of Justice Holmes in his landmark takings opinion provides useful perspective when considering the theoretical basis of the takings doctrine. Holmes reminds us that "... the question at bottom is upon whom the loss of the changes desired should fall" *(Pennsylvania Coal Company v. Mahon*, 260 U.S. 393, 416 [1922], quoted by Justice Rehnquist, dissenting, in *Penn Central Transportation Co. v. New York City*, 438 U.S. 104, 148 [1978]).

More importantly, "we are in danger of forgetting that a strong desire to improve the public condition is not enough to warrant achieving the desire by a shorter cut than the constitutional way of paying for the change" (*Pennsylvania Coal Company v. Mahon*, 260 U.S. 393, 416 [1922], quoted by Justice Rehnquist, dissenting, *Penn Central*, p 152). "The protection of private property in the Fifth Amendment presupposes that it is wanted for public use, but provides that it shall not be taken for such use without compensation" (*Pennsylvania Coal Co. v. Mahon*, p 415). "When this seemingly absolute protection is found to be qualified by the police power, the natural tendency of human nature is to extend the qualification more and more until at last private property disappears. But that cannot be accomplished in this way under the Constitution of the United States" (*Mahon*, p 415).

Although the goal of environmental protection is very important, that goal may not be accomplished by ignoring the U.S. Constitution. The Virginia Chesapeake Bay Preservation act attempts to preserve Chesapeake Bay while obeying constitutional mandates. However, the attempt at a careful balance still leaves questions.

To provide fairness to landowners, to avoid litigation, and to ensure that the recipient of public benefits pays for the benefits, additional efforts could be creatively used to resolve the takings question. For example, real estate taxes on the buffer area could be forgone. Federal agricultural programs such as the Conservation Reserve Program could be used to "rent" the buffer from the landowner. The cost of adopting BMPs could be subsidized by governmental funds or tax credit. Conservation easements could be used to reduce the cost of leaving the buffer area idle.

Society, the beneficiary of clean water, would share in the cost, via direct transfer payments or reduced tax revenues. Together, these alternatives ensure fairness for the landowner, avoid litigation of the takings question, and could result in a more congenial resolution of the clean water issue.

In any case, policy makers should consider alternatives that would shift the decision making burden from the courts to the legislature. The choice of " . . . upon whom the loss of the changes desired should fall" (*Pennsylvania Coal*) is ultimately a choice best left to the legislature.

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Toward a Sustainable Coastal Watershed:
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Community-Based Pollution Prevention Planning as a Key Component of Water Quality Management in the Chesapeake Bay Basin—The Tidewater Interagency Pollution Prevention Program Example

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Abstract: In order to meet water quality planning objectives, traditional management approaches must be broadened to incorporate new solutions for complex, multimedia environmental problems. One of the most promising approaches from a cost and pollutant reduction perspective is pollution prevention. Within the Chesapeake Bay region, innovative pollution prevention approaches are being developed and implemented as part of the Tidewater Interagency Pollution Prevention Program (TIPPP).

The TIPPP is a model community demonstration program, initiated in 1991 as a cooperative effort between the U.S. Environmental Protection Agency (EPA), the Department of Defense (DoD), the National aeronautics and Space Administration, the U.S. Air Force, and the U.S. Army, designed to develop comprehensive, multimedia pollution prevention strategies for key military and or research installations within the Chesapeake Bay basin. The TIPPP planning process addresses point and nonpoint sources of pollution, including land management, stormwater runoff, new construction, vehicle operations, and manufacturing processes.

This paper presents an overview of the TIPPP pollution prevention planning approach, focusing on the conduct of pollution prevention opportunity assessments and the subsequent development and implementation of installation-wide pollution prevention plans. In particular, the pollution prevention opportunity assessments are a critical component of the overall TIPPP process and serve as the basis for any comprehensive, community-based pollution prevention planning effort. Expertise gained on how to conduct effective multimedia pollution prevention opportunity assessments are shared in this paper. As well, preliminary results on TIPPP program effectiveness, focusing on innovative and cost-effective solutions, are provided. Building on these results, this paper provides an overview of a comprehensive pollution prevention planning approach that could be adopted by other communities and installations seeking to use pollution prevention as a way to better contribute to the overall restoration of the Chesapeake Bay.

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State Resource Management and the Federal Wetlands Program: Can States Assume the Federal Role and Expertise in Protecting Wetlands?

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Abstract: Traditionally, the federal government has taken the lead in regulating and managing activities in wetlands under Section 404 of the Clean Water Act. The Clinton administration has called for increasing the role of states in the protection and management of these vital natural resources. Several federal agencies, including the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service (FWS), and the National Marine Fisheries Service (NMFS) have distinct responsibilities in the protection of wetlands pursuant to several federal environmental statutes. The state assumption of this federal program raises numerous issues as to how to maintain the expertise and roles of these agencies to ensure that wetlands receive no less protection under a state program than under the existing federal program.

For example, the paper addresses how to maintain the FWS and NMFS responsibilities under the Endangered Species Act to issue biological opinions in cases where a federally listed species or its critical habitat may be affected. The paper discusses this issue, and the role of citizens and other critical components of the federal program, and it recommends how to maintain the federal protections in the context of a state program to ensure effective resource management.

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THE PEOPLE ARE SPEAKING/THE CHESAPEAKE COUNTRYSIDE IS CALLING—RESEARCH AND MANAGEMENT NEEDS FOR SUSTAINABLE LAND PLANNING

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Abstract: The Chesapeake Bay Region Countryside Stewardship Exchange, a cooperative effort of the Countryside Institute, Alliance for the Chesapeake Bay, National Park Service, and Chesapeake Bay Program is undertaking three intensive 10-day study sessions in the watershed in September 1994. These three studies were chosen from among fourteen proposals received from broad-based coalitions of community groups and local governments that are seeking technical expertise and assistance from teams of planning, land management , and resource specialists. Each team will visit one specific site (county, watershed, community etc.) to evaluate and make recommendations for protecting the land and watershed, maintaining sustainable development, historic landscapes, and the general preservation and enhancement of the rural and environmental character of the area.

This paper briefly reviews the fourteen submitted proposals to determine what both the common as well as the unique issues and concerns say about the future sustainability of the Bay watershed. The watershed and land management concerns of the exchange groups hosting the study teams are to elaborated through interviews. Particular attention are given to what questions the locally-generated proposals raise about broader watershed management-oriented research needs. The paper also comment s on other ongoing sustainable management or development efforts in the Chesapeake Bay watershed and suggest how the Chesapeake Bay Program could address these concerns from a more holistic watershed management-oriented research and policy development.

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SUBMERGED AQUATIC VEGETATION: A SUCCESSFUL EXAMPLE OF AN INTEGRATED SCIENTIFIC AND MANAGEMENT APPROACH TO PROTECTION AND RESTORATION OF A BAY RESOURCE

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Abstract: Over the last three to four decades, the declines in many species in Chesapeake Bay that have resulted from overharvesting, deterioration of water quality, habitat destruction, disease, and/or meteorological changes have alarmed scientists, managers, politicians, and the public. This concern has resulted in scientific studies designed to document the magnitude and causes of the declines, and in basinwide agreements intended to protect, restore, and enhance these living resources. The dramatic Bay-wide declines in submerged aquatic vegetation (SAV) in the 1960s and 1970s, which was correlated with increasing nutrient and sediment inputs from development of the surrounding watershed, galvanized a diverse group of scientists and managers into forging a link between future research directions with anticipated resource management needs.

This continual feedback loop between scientific hypothesis testing and management implementation built the technical foundation for the *Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis*. The initial findings emerging from the technical synthesis and the Baywide aerial survey supported the formulation of the *Submerged Aquatic Vegetation Policy for the -Chesapeake Bay and Tidal Tributaries* and the *Implementation Plan for the Submerged Aquatic Vegetation Policy* —policy documents that now guide managers and scientists in areas of SAV assessment, protection, edcation, and research, so as to ensure the future of SAV in Chesapeake Bay.

From this now decade-long experience, a series of lessons learned about forging and maintaining successful, mutually rewarding interactions between scientific investigations and management implementation are presented in this paper.